Investment Case for Agricultural Lime in TANZANIA

August 2023

CIMMYT

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I. Executive Summary

Lime is a viable solution to treat the highly acidic soils in Tanzania

Lime is a viable solution to treat soil acidity due to its impact on acid soils over a relatively short period of time, in-country availability, and relatively low cost (as a raw material). Soil acidity inhibits root growth and nutrient absorption, reducing yields of major cash crops (e.g., cotton) and staple crops (e.g., maize, rice, beans, and cassava) in Tanzania. Reduced crop productivity threatens the food security of the country – with an estimated 15% of rural households classified as food insecure and 15% more at risk of becoming food insecure[1,2] - and adversely impacts employment. While several solutions address soil acidity, including organic fertilizers (e.g., animal manures and compost), acid-tolerant varieties, and wood ash, lime is the most easily available and effective. Localized studies in Tanzania show that lime application on different crops to address soil acidity has the potential to significantly improve crop yield – up to 50% in maize and 360% in beans.[3] *

However, achieving significant uptake of lime is complex

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

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

Lime is bulky, and large volumes are needed to treat farmland. While the amount of fertilizer and other inputs farmers often use are measured in kilograms per hectare (ha), lime use is typically measured in tons per ha. This presents a particular challenge for Tanzanian farmers, who often use non-motorized transport to deliver inputs to their agricultural plots. Nevertheless, it is important to note that fertilizers are used every season while lime can be used once every three to four years to manage soil acidity.

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

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

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

2 Tanzanian Food Security and Health, n.d.; Integrated Food Security Phase Classification (IPC), Tanzania, IPC, Acute Food Insecurity Analysis, 2020

3 AFAP, Lime Study, 2018

* **Note:** data for beans were obtained from a beans research program at Selian, Research Institute, conducted in Manyara region, sourced from the Lime Scoping Study, Tanzania 2017. Data for maize came from Clinton Development Initiative (CDI) in which 62 maize demonstration plots were implemented in 2014/15 and 2015/16 seasons in Kilolo district Iringa region.

In Tanzania, the SAGCOT and Lake Zone regions possess just under 50% (14 million ha) of the total cropland in the country, of which 14% is highly acidic (pH<5.5).[4] Moreover, these two regions produce 55% of the country's food and cash crops.[5]

In SAGCOT, bean, potato, sweet potato, and tobacco have the highest potential economic surplus. Combined, these crops require 100,375metric tons (MT) of lime to treat soil acidity with the potential to generate 14.4million USD economic surplus, and a 10.04 million USD market for lime producers, at a price of 100 USD/MT of lime.[6,7] This level of economic surplus makes lime a commercially viable opportunity for farmers in these crops. However, the quantity of lime required is small, likely resulting in underutilized manufacturing capacity and therefore high production cost.

In the Lake Zone province, bean, sweet potato, ground nut, banana, chickpea, potato, and tobacco potentially produce the highest economic surplus as a result of using lime. Combined, these crops need 656,635MT of lime to treat soil acidity and can in turn generate approximately 206.6 million USD additional revenue by the third year.[8] This translates into approximately 100.1 million USD in economic surplus, and approximately 65.7 million USD market for lime producers, at the current price of lime, i.e. 100 USD/MT[9]. This level of economic surplus makes lime a commercially viable opportunity for these crops.

These crops are selected based on currently available yield response to exchangeable acidity data and show the potential economic surplus of lime application in target regions. With additional yield response data, the analysis can be repeated to determine the economic value of using lime on other nationally important crops such as horticultural crops like avocados and snap peas.

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

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

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

Improving the commercial viability of supplying lime at the required level of quality and cost will look different for the SAGCOT and Lake Zone regions. In the Lake Zone, for instance, there is a need to establish distribution centers closer to farmers given that the closest production plant is located in Dodoma (over 500 km away).

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

4 CIMMYT, GAIA ex-ante analysis
5 National Institute of Statistics Rwanda, Seasonal Agricultural Survey, 2021
6 Considering a residual effect of 50% in year 2 and 25% in year 3 after applying lime
7 CIMMYT data, 2022
8 Considering a residual effect of 50% in year 2 and 25% in year 3 after applying lime
9 Ibid
10 AFAP, Lime Study, 2018; Dalberg, Stakeholder interviews, 2022

There is an urgent and critical need to strengthen the base of evidence in terms of different crop yield responses to lime and the impact of various factors (such as levels of pH and soil conditions) on yield response, before large investments are made in the sector. The yield response data used to develop this analysis are preliminary, making it difficult to make conclusive recommendations. Hence, it is critical to refine these data before large investments are made in the lime sector.

Beyond lime, testing and comparing the effects of other potential interventions for management of soil acidity is essential to select the most appropriate course of action. Lower cost alternatives and solutions for acid soil management may emerge which can improve crop yield and farmer livelihoods more efficiently and cost effectively compared to lime. For example, consideration of upstream solutions to limit the spread of acidic soils. This entails the promotion of non-acidifying fertilizers such as Single Super Phosphate (SSP), Calcium Ammonium Nitrogen (CAN), and Nitrogen Phosphorous Potassium (NPK), and Mavuno (crop specific blended fertilizers).[11] This can be achieved by working with fertilizer manufacturers and agro dealers to promote the use of non-acidifying fertilizers and driving awareness among farmers on the effects of acidifying fertilizers on soils and crop yields. However, there are tradeoffs to using non-acidifying fertilizers such as higher transport and labor costs. Such fertilizers have a higher application rate as they require more quantities to provide the same amount of nitrogen as acidifying fertilizers such as Diammonium Phosphate (DAP) and urea which have higher nitrogen concentrations.

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

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

II. Defining the challenge

Agriculture is a key sector in Tanzania which supports the livelihoods of most of the population. In Tanzania, agriculture accounts for 27% of GDP,[12] provides a livelihood to 65% of the country's labor force,[13] and accounts for around 10% of foreign exchange earnings.[14] The government of Tanzania intends to transform the agricultural sector towards higher productivity, increased commercialization and improved livelihoods for smallholders, and improved food nutrition and security nationally.[15]

However, competitiveness and productivity in the agricultural sector are inhibited by acidic soils in key crop-growing regions. Currently, 14.3% of Tanzania's 32.7 million ha of cropland are acidic. Acidity is prominent in the Southern Agricultural Growth Corridor of Tanzania (SAGCOT) regions and the Lake Zone regions, which grow most of the country's food and cash crops. The SAGCOT region, for instance, is often considered a breadbasket region for staple crop production not only for Tanzania but also for its bordering land-locked countries. Soil acidity inhibits root growth and nutrient absorption, reducing yields of major cash crops such as cashew nuts, coffee, and cotton as well as staple crops such as maize and beans. For instance, maize faces a 40% loss in production efficiency in acid soil.[16] The loss in production efficiency means that only 2.2 million metric tons (MT) of maize are produced in acid soil against potential production of 5.5 million MT. Reduction in agricultural productivity in these key regions and for major crops threatens the food security of the country and adversely impacts employment and livelihoods.

Agricultural lime is the most viable, effective, and easily accessible method of treating soil acidity, due to an abundance of lime reserves in Tanzania. Lime is a viable solution compared to alternatives due to its impact on acid soils over a relatively short period of time, in-country availability, and low cost (as a raw material). Conversations with two lime manufacturers with lime mining rights indicated sufficient high-quality lime reserves in Tanzania. One manufacturer possessed 126 ha for limestone mining (eight million tons of limestone) and another 80ha of limestone (assumed to be ~five million tons[17]), which can be mined for the next 100 years.* Beyond these two lime deposits, there are numerous others located in different areas of Tanzania, although the quality of lime at these deposits remains unverified.

However, realizing significant uptake of lime is complex primarily due to several interrelated factors, including (i) yield response to lime not being accurately quantifiable; (ii) it can often take more than a year before the full yield response of lime is evident/measurable, as residual responses to lime can occur in the second and third year; and (iii) yield response being dependent on a number of variable factors including soil properties, level of acidity, crop type, variety, the residual effect of lime and other factors such as rainfall pattern. Consequently, there is limited proof of concept – leading to the current low uptake of lime.

The lack of demand for lime is a key binding constraint to its effective supply and use. Despite smallholder farmers contributing the majority (75%) of Tanzania's agricultural production, current demand for lime is restricted to large commercial farmers and a few local government authorities, supported by civil society for demonstration plot use. Despite efforts by the government and development partners to raise awareness by providing lime for free for demonstration purposes in selected regions of the country, these efforts are yet to yield success due to lime awareness being limited only to demonstration areas rather than at a national

[12] Statista, Share of agriculture in the GDP of Tanzania from 2012-2020, 2020

[13] Statista, Employment in the agriculture sector as a share of total employment in Tanzania, 2020

[14] Tanzania Invest, Tanzania Agriculture, 2022

[15] The United Republic of Tanzania, Agriculture Sector Development Programme II (ASDP TWO), 2022

[16] AFAP, Lime Scoping Study, 2018

[17] Based on ~8m tons divided by 126 hectares equates to ~63500 tons per hector. Assuming similar dimension of depth of reserves and that lime deposits in Tanzania are evenly spread

* **Note:** There are differences in how limestone deposits are evaluated in Tanzania, with some analyses including the amount of lime deposits in tons, while other analyses record the thickness of lime or the geographic coverage (acreage) of lime.

scale, and awareness not translating to behaviour change in smallholders purchase and use of lime. Due to a combination of both limited awareness of soil acidity issues and smallholders cash flow challenges, demand for lime among smallholders remains severely low, despite its critical need. Demand challenges are exacerbated by the high price of lime, and the lack of policies that protect smallholders' investments on the land they farm, as most of them are tenants rather than owners of farming land. Consequently, the need to address soil acidity to achieve improved crop productivity remains largely unheeded by smallholders who produce most of the country's crops.

In addition to low demand, the supply of lime is impeded by cost factors which raise its final price, creating a vicious cycle of low demand and inefficient supply. Distribution costs account for 60% of the total end-use cost of lime, which is a significant amount for the average smallholders whose average earnings are estimated at $516 - $1032 per annum. Challenges across each node of the supply chain - lack of mechanization at the mining stage, unreliable electricity increasing machine downtime at the processing stage, and high transportation costs at the distribution stage - have contributed to cost inefficiencies in the supply chain which have contributed to making lime unaffordable for smallholders. Moreover, lack of competition in the sector due to limited demand eliminates price reductions that could occur due to price competition. With insufficient evidence of demand, there has been little incentive to address these supply-side challenges nor attract private sector participation/investment in the sector. Without interventions, the gap between demand and supply will remain sizable in Tanzania.

The lime sector faces challenges across demand, supply, and the enabling environment that limit the industry's growth. Demand constraints include limited farmer awareness of the impact of soil acidity on crop farming and methods for mitigation. Lime suppliers face significant underutilized capacity, which drives up their costs. Additionally, suppliers contend with high transportation costs, worsened by limited demand and informality of transportation networks. Furthermore, challenges with securing sufficient and quality storage for the finished product of lime due to its bulkiness and dustiness drive up lime distribution costs. Limited policy initiatives supporting efficient production of lime and high fees and levies also influence and increase costs and final prices of lime.

Category	Binding constraints
Demand 	• **Limited awareness of the importance of soil health and little knowledge of soil acidity management** have contributed to low demand for lime • **Cost factors also influence demand for lime particularly for smallholder farmers.** Existing demand is largely driven by commercial farmers • **The high cost of lime to the end consumer is largely driven by the cost of distribution;** distribution accounts for around 60% of the final price of lime
Supply 	• **Limited warehousing facilities** affect lime processors' ability to produce lime in a timely manner and ensure high utilization • **Distribution is a binding constraint in the supply chain,** driven by limited demand, diseconomies of scale, and informality in transport systems • **Few agro-dealers stock lime,** and those who do are less rurally located. Generally, agro dealers face a lack of adequate storage facilities for lime
Enabling environment 	• While the Government of Tanzania has made **strides towards increasing soil testingby supplying mobile soil testing kits, the kits are barely used,** and most smallholder farmers (smallholders) do not test their soil before using inputs such as lime • **Lime is currently taxed as a mineral** rather than an agricultural input in Tanzania, accumulating several royalties and fees • While there has been considerable government effort towards encouraging fertilizer use across the country, there has been **limited encouragement of lime use, arising from limited understanding of soilhealth and productivity challenges posed by soil acidity**

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

On the demand side, the use of lime is relatively nascent, and demand is low due to the difficulty in determining the actual benefit of lime in most contexts.[18] Measuring the uptake and effects of lime is complex as the reaction time and impact of lime can depend on soil properties, level of acidity, crop type, variety, rainfall pattern, and several other factors. As a result, the lime reaction time range from 6 months to over three years. Contrastingly, fertilizer application yields almost immediate results for the farmer. Therefore, advocating for lime to farmers is challenging. Lime's dependency on a multitude of factors for success, its requirement for re-investment (application of lime) over multiple seasons, high cost, and the time it takes to yield results cause farmer hesitancy towards adoption. High prices of lime are a particularly salient barrier to the adoption of lime by smallholders and high distribution costs account for the bulk of these high lime prices. While the factory gate price of lime is USD 58 per metric ton (MT), farmgate prices are approximately 130 USD per ton and vary depending on the distance. On average, acidic soil needs 2 MT of lime per ha. Meanwhile, smallholder farmers' annual income ranges from USD 516- 1032; thus, per ha, the farmgate costs of lime amount to about 12-25% of smallholders annual income.*[19]

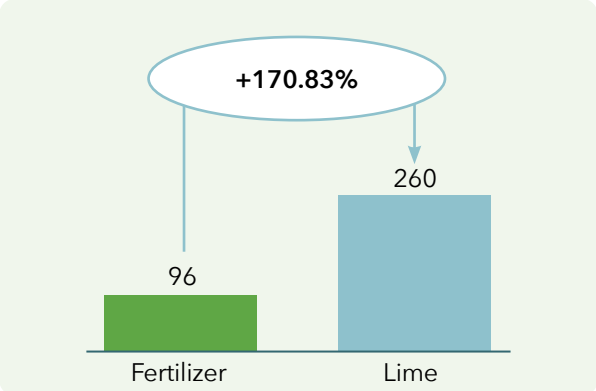

Figure 2: Cost per hectare of lime vs fertilizer

Limited demand triggers uneconomical supply – caused by underutilized production capacity and inefficient distribution channels – resulting in high costs of producing lime, making the sector unattractive for private investment. Agricultural lime is processed and supplied by two private sector processing plants, Dodoma Cement and Tanga Cement. These processors have vast amounts of underutilized capacity due to the low demand for lime. For instance, Dodoma cement uses only about 40% of its installed capacity for lime processing. Limited storage capacity and quality affect manufacturers' ability to stabilize the utilized capacity of their plants as they cannot produce lime and store it for on-demand distribution. In addition, lime manufacturers' uncertainty around demand for a particular season and relatively low quantities demanded from loyal customers compared to plant capacity disincentivizes investment in storage. Underutilization of capacity due to low demand means that lime processors cannot benefit from economies of scale to lower their costs. Low demand for lime also limits competition as there is little incentive for new entrants in the supply of lime. With few competitors on the supply side of lime, there is no price competition. Consequently, the two suppliers can establish high prices of lime to recoup investment costs and maximize their margins. These high prices contribute to the exclusion of most smallholders (who would compose the majority of lime demand in Tanzania) from purchasing and using lime, perpetuating the vicious cycle of low demand and supply, resulting in the market failure of the lime sector.

Estimated cost breakdown of 1 metric ton of lime from production to end consumer
USD per ton of lime

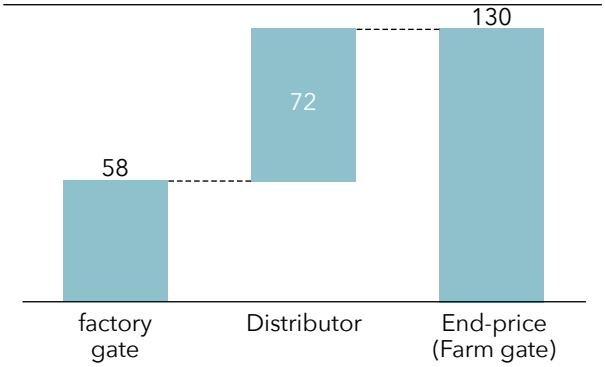

Figure 3: Cost breakdown of 1 MT of lime

[18] Dalberg analysis, 2022

[19] **Note:** Costs per hectare of lime calculated using 2MT of lime per hectare in one year. Costs of fertilizer assume DAP fertilizer used, taking maize as an example where only 87kg per ha is needed, a 50kg bag of fertilizer is TZS 55,600/=, and fertilizer is used for 2 planting seasons in one year.

As a result, the commercial viability of lime is currently questionable, making the sector unattractive for both farmer and supplier investment. On the demand side, low farmer awareness of the need for lime and high prices prevent uptake and use. On the supply side, restricted and seasonal demand leads to idle production capacity, which drives up costs, limiting the appetite for further investment in the sector or improving production efficiencies.

Consequently, solutions need to determine the commercial viability of lime and address bottlenecks across the value chain, particularly around demand creation. Demand-side interventions include targeted awareness drives in highly soil acidic regions through farmer Good Agricultural Practices (GAP) training programs presenting the importance of soil acidity management for agricultural productivity. Where relevant, the economic case for using lime can be presented to farmers to farmers. In parallel, supply-side actors can explore options for improving the commercial viability of supplying lime through partnerships and optimizing distribution and storage networks. It is important to note that there is likely to be a limited desire to invest in solving supply-side challenges without increased demand. Identifying appropriate pathways that demonstrate commercial viability requires the support of the enabling environment. Complementary enabling environment interventions that improve the policy environment to reduce production costs and improve access to affordable finance to support suppliers are critical to the growth of the lime sector. Furthermore, there is a need to focus interventions on target markets (acidic regions with optimal crop yield responses to lime resulting in an economic surplus) to start building the economic case for lime to farmers and providing proof of concept.

Source: IPP Media, Ministry cuts DAP urea fertilizer prices, 2020; AGRA, Assessment of Fertilizer Distribution Systems and Opportunities for Developing Fertilizer Blends TANZANIA, 2018

III. Identification of priority markets

Our approach to building an investment case for lime is anchored on the need to identify nodes of entry that are likely to move the needle in terms of economic benefit of lime for suppliers and farmers. Nodes of entry are defined as areas with crops that are likely to generate the highest economic surplus with lime application and can serve as proof of concept for scaling lime uptake across the country in the longer term. Economic surplus was calculated using (the total hectares (ha) of the crop * yield improvement * farmgate price) – (total lime needed * price of lime). This study primarily focuses on the economic surplus achieved within one growing season (to articulate the demonstration effect and simplify assumptions such as the time value of money for the poor). However, it is important to note that liming has multi-year benefits.

To identify the nodes of entry, we used a two-step process:

STEP 1: SELECTION OF RELEVANT CROPS

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

STEP 2: BUILDING THE ECONOMIC CASE FOR LIME

The economic benefit of lime application on shortlisted crops is calculated and used to create heat maps to identify the highest potential economic value regions. As shown in Figure 4, the economic benefit of lime calculates the return on investment for a farmer (per MT) due to the application of lime by considering yield increases and translating that to net monetary returns.

Note: Consequently, we calculated the benefit potentially accrued in future years by determining the residual benefit in future years – by using a discount rate of 50% in year 2 after lime application and 25% in year 3 after lime application. Moreover, crops were selected based on currently available yield response data and show the economic surplus of lime application in target regions. With additional yield response data, the analysis can be repeated to determine the economic value of using lime on other crops with initial demand for lime such as avocado.

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

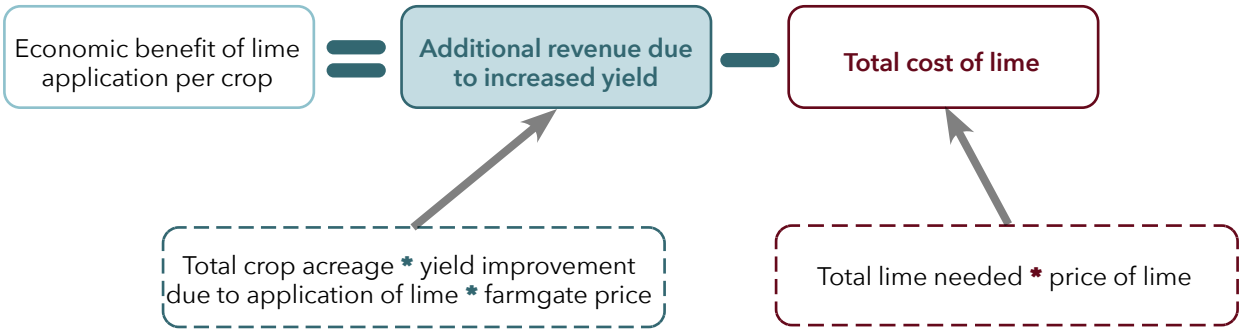

Figure 4: Economic benefits of lime application per crop calculation formula

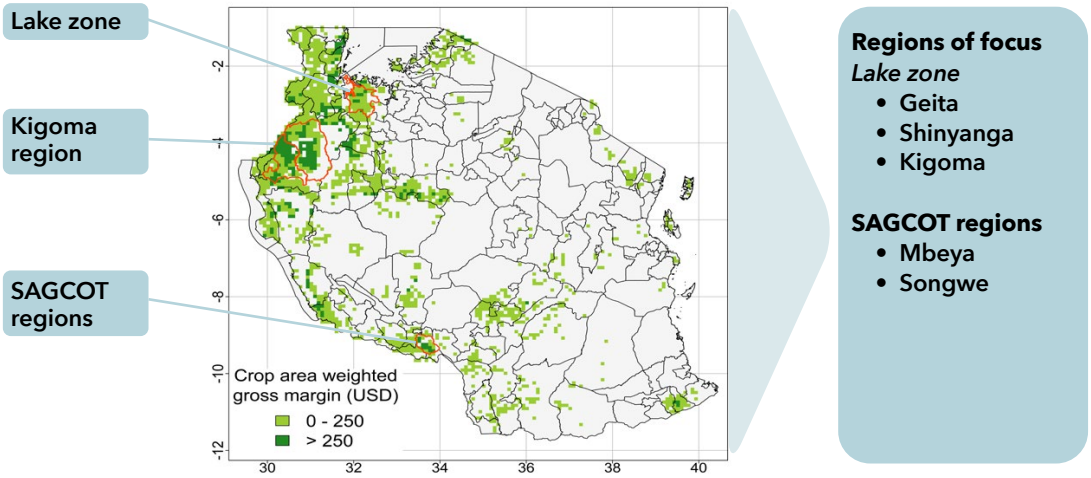

Figure 5: Highest economic value areas in Tanzania

This approach enables us to size the overall economic benefit of lime, in relevant regions, for lime producers and farmers. The primary benefit for both lime producers and farmers is financial returns. Assuming the potential demand reflected in the market, lime producers are incentivized to improve production capacity to reduce the cost of production. Assessment of current realities in the production and distribution of lime is required to pinpoint supply-side interventions needed to ensure adequate quality of lime, at an appropriate price to farmers, based on the expected economic surplus. On the demand side, farmers can generate additional income due to improved crop yield and reduced price of lime.

IV. Economic opportunity for lime

The Southern Agricultural Growth Corridor of Tanzania (SAGCOT) regions and Lake Zone regions in Tanzania provide the greatest potential to increase farmer productivity through acidic soil remediation. Key regions in these zones with particularly high economic surplus are Mbeya and Songwe in SAGCOT and Geita, Shinyanga, and Kigoma in the Lake Zone. A series of conditions that make these regions feasible starting points for lime investments are detailed in the subsequent paragraphs. The analysis on crops is based on liming yield response to exchangeable acidity and resulted in residual crop selection. Therefore, from the analysis, key crops with the highest economic surplus are bean, potato, sweet potato, and tobacco in SAGCOT and bean, sweet potato, ground nut, banana, chickpea, potato, and tobacco in the Lake Zone. Nevertheless, on the ground, we know that liming is used for maize and avocados in select areas of the SAGCOT region, while in the Lake Zone, alternative methods for management of soil acidity are used such as wood ash on various crops. In addition, cassava and tubers are generally acid tolerant, and therefore can still produce high enough yields in acidic soils.

Table 1: Summary of economic opportunities for lime in SAGCOT and the Lake Zone for key crops

	SAGCOT	Lake Zone
Total market size for lime (MT)	100,375.3	656,635.5
Total market size for lime producers (USD)[20]	10,037,530	65,663,550
Total economic surplus (USD)[21]	14,407,957.58	100,126,598.70

Opportunities in SAGCOT

SAGCOT possesses over 30% of the total cropland in the country,[22,23] accounts for the production of about 40% of the country's food and cash crops and hosts around 2.3 million farmers (25% of farmers in the country).[24,25] Some food crops produced in the region are exported to southern neighboring landlocked countries providing an opportunity to smallholders for commercialization. Of the nine regions that make up the SAGCOT (Iringa, Njombe, Mbeya, Songwe, Rukwa, Katavi, Ruvuma, and small parts of Lindi and Mtwara), Mbeya and Songwe are of concern due to their acid soils and associated positive economic returns due to lime application. On average, 31% (~2,338,276 ha) of the cropland in this region has a pH between 5.5 and 6.5, and 7% (~517,965 ha) of the cropland has a pH of less than 5.5.[26,27] Analysis done on 26 crops grown in Tanzania indicates a total lime need in this region of 16,860 MT in the first year.[28] While this region is in close proximity to lime deposits in Songwe, it is far from lime processors located in Dodoma and Tanga in Central and Eastern Tanzania. The closest lime processor is located in Dodoma, approximately 250 km away.

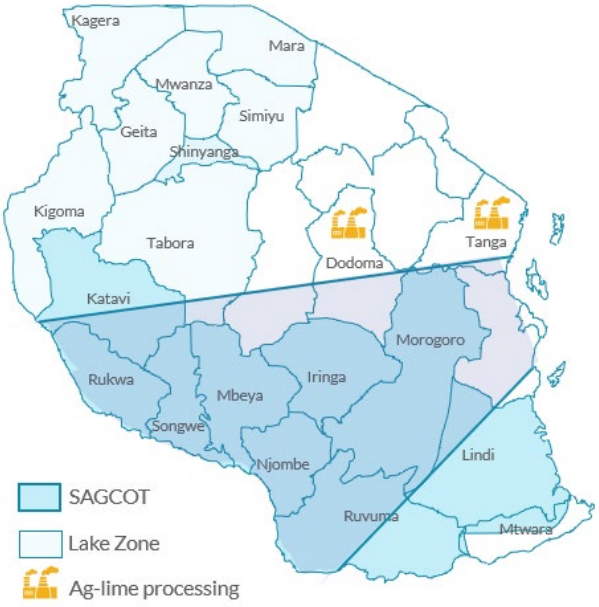

Figure 6: High economic value areas based on acidity, agricultural production, and proximity to lime processors

[20] Calculation assumes cost of lime is $100 USD/MT
[21] CIMMYT, 2022; Note: calculations are based on the sum of the first three years of surplus.
[22] NBS, 2016-17 Annual Agricultural Sample Survey Report, 2016
[23] AFAP, Liming study Tanzania, 2018
[24] FEWS Net, Tanzania Market Fundamentals Summary, 2018; USDA GAIN Annual Report 2019, Tanzania Corn, Wheat, and Rice Report, 2019
[25] FinScope Tanzania, Dedicated Farmers, 2017
[26] CIMMYT, 2022
[27] Southern Agricultural Growth Corridor of Tanzania Investment Blueprint, Chapter 4. The Southern Agricultural Growth Corridor: current status of agriculture, 2011
[28] CIMMYT, 2022

An analysis of crops with the highest gross margins after lime application in the region highlights bean, potato, sweat potato and tobacco as key crops of focus as they generate the highest economic returns.

Combined, these crops require 100,375.32 MT of lime to treat soil acidity in the first year and can in turn generate 18.9 million USD additional revenue in the first year. Assuming the price of lime to be 100 USD/MT, this translates into an economic surplus of 8.9 million USD[29] within the first year and ~14.4million USD by the third year.[30] The table below provides details about these crops assuming no residual effect due to lime application.

Opportunities in the Lake Zone

In the Lake Zone, 9.9% of the cropland is highly acidic (pH<5.5) and the region accounts for ~16% of the country's cropland as well as significant production of food and cash crops. The Lake Zone is composed of eight regions accounting for 16% of total cropland in the country, of which 9.9% is highly acidic (pH<5.5). Of the eight regions, Geita, Shinyanga, and Kigoma are of concern due to their acidic soils and associated positive returns from liming. On average, 31% (~1,988,485 ha) of the cropland in this region has a pH between 5.5 and 6.0, and 10% (~638,819 ha) of the cropland has a pH of less than 5.5.[31,32] The analysis conducted on 26 crops indicates that the total lime needed in this region is 68,892 MT in the first year.[33] This region is much farther away from lime deposits and ag-lime processors located in Dodoma and Tanga in Central and Eastern Tanzania. The closest lime processor is located in Dodoma, approximately 600 km away.

An analysis of crops with highest gross margins after lime application in the region highlights bean, sweet potato, ground nut, banana, chickpea, potato and tobacco as key crops of focus as they generate the highest economic returns.

Combined, these crops need 656,635.48MT of lime to treat soil acidity in the first year and can in turn generate 127.3 million USD additional revenue in the first year and 206.6 million USD by the third year. Assuming the price of lime to be 100USD/MT, this translates into an economic surplus of ~61.6 million USD[34] within the first year and ~100.1 million USD by the third year.[35] The table below provide details about these crops.

Table 2: Crops with the highest economic surplus in SAGCOT

	BEAN	POTATO	SWEET POTATO	TOBACCO
Current area under production (ha)	47,604.8	70,025.64	49,079.8	1,496.87
Yield increase from lime application (MT/ha)	0.3756	0.1483	0.1062	0.0030
Yield response to exchangeable acidity from liming (MT)	17,881.8	10,386.4	5,211.19	4.43
Total demand for lime (MT)	82,323.07	9,456.4	8,497.26	98.59
Grain market price (USD/MT)	722.4	429.85	290.7	2960
1st year total additional revenue (USD)	12,900,000	4,464,586	1,514,893	13,112.8
Total additional revenue by the third year (USD)	21,000,000	7,249,677	2,459,911	21,292.81
Current cost of lime at the farmgate (USD/MT)	100	100	100	100
Total cost of lime needed in the 1st year (USD)	8,232,307	945,640	849,726	9,859
Economic surplus within one year (USD)	4,685,521	3,518,946	665,167	3,253.8
Total economic surplus by the third year (USD)	7,608,435	5,714,129	1,080,110	5,283.58

[29] CIMMYT, 2022

[30] Ibid. Note: total for the first 3 years - calculated using a 50% discount rate for the second year and a 25% discount rate for the third year

[31] CIMMYT, 2022

[32] Southern Agricultural Growth Corridor of Tanzania Investment Blueprint, Chapter 4. The Southern Agricultural Growth Corridor: status of agriculture, 2011

[33] CIMMYT, 2022

[34] CIMMYT, 2022

[35] Ibid, calculated using a 50% discount rate for the second year and a 25% discount rate for the third year.

Table 3: Crops with the highest economic surplus in the Lake Zone

Items	Crops from HP analysis						
	BEAN	SWEET POTATO	GROUND NUT	BANANA	CHICKPEA	POTATO	TOBACCO
Current area under production (ha)	237,996.7	259,514.8	31,462.89	78,660.07	3,914.74	3,327.7	4,914.38
Yield increase from lime application (MT/ha)	0.4589	0.2792	0.6250	0.3245	0.6938	0.5737	0.0594
Yield increase from lime application (MT)	109214	72457.1	19665.1	25528.5	2716.22	1909.17	292.02
Total demand for lime (MT)	440,054.4	75,240.99	64,077.46	67,369.72	5,065.63	1972.44	2,854.84
Market price (USD/MT)	722.4	290.7	619.45	454.9	681	429.85	2960
1st year total additional revenue (USD)	78,900,000	21,100,000	12,200,000	11,600,000	1,849,746	820,656.70	864,379.20
Total additional revenue by the third year (USD)	128,000,000	34,200,000	19,800,000	18,900,000	3,003,652	1,332,598	1,403,595
Current cost of lime at the farmgate (USD/MT)	100	100	100	100	100	100	100
Total cost of lime needed in the 1st year (USD)	44,005,435	7,524,099	6,407,746	6,736,972	506,563	197,244	285,484
Economic surplus within one year (USD)	34,900,000	13,500,000	5,773,770	4,875,933	1,343,183	623,412.7	578,895.2
Total economic surplus by the third year (USD)	56,700,000	22,000,000	9,375,554	7,917,630	2,181,085	1,012,309	940,020.7

Key Sensitivities

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

A 20% decrease in the price of lime leads to a more than 22.75% increase in the total economic surplus generated from liming of bean, potato, sweet potato, and tobacco in the SAGCOT.

A 20% decrease in the price of lime leads to a 21.26% increase in the total economic surplus generated from liming of bean, sweet potato, ground nut, banana, chickpea, potato, and tobacco in the Lake Zone.

The output price or price of the crop has a significant input on the economic surplus a farmer obtains compared to changes in the price of lime.

Table 4: Sensitivity analysis of the economic surplus due to liming in SAGCOT

Description		Value [lime price: 100USD/MT]	Value [lime price: 80 USD/MT]	% Increase
Bean	Economic surplus by year 3[36]	7,608,435	10,300,000	35.14%
Potato	Economic surplus by year 3[37]	5,714,129	6,021,239	5.37%
Sweet potato	Economic surplus by year 3	1,080,110	1,356,071	25.55%
Tobacco	Economic surplus by year 3	5,283.58	8,485.43	60.6%
TOTAL	Economic surplus by year 3[38]	14,407,957.58	17,685,795.43	22.75%

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

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

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

Table 5: Sensitivity analysis of the economic surplus due to liming in the Lake Zone

Description		Value [lime price: 100USD/MT]	Value [lime price: 80 USD/MT]	% Increase
Bean	Economic surplus by year 3	56,700,000	70,900,000	25.22%
Sweet potato	Economic surplus by year 3	22,000,000	24,400,000	11.11%
Ground nut	Economic surplus by year 3	9,375,554	11,500,000	22.20%
Banana	Economic surplus by year 3	7,917,630	10,100,000	27.63%
Chickpea	Economic surplus by year 3	2,181,085	2,345,598	7.54%
Potato	Economic surplus by year 3	1,012,309	1,076,367	6.33%
Tobacco	Economic surplus by year 3	940,020.7	1,032,735	9.86%
TOTAL	Economic surplus by year 3[39]	100,126,598.7	121,354,700	21.2%

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

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

A range of interventions across the lime value chain are necessary to increase the uptake of lime where it is needed and understand the commercial viability of supplying lime at the required level of quality and cost. These activities can be concentrated in the SAGCOT and Lake Zone regions to begin with and should include further studies to test the economic viability of lime in areas with acidity. Pilot demand initiatives can include demonstration plots, the use of champions to advocate for lime use, farmer subsidies, and pooled buying (to reduce distribution costs and streamline distribution). Pilot supply activities can include targeting producers and investing in storage closer to the end consumer. The enabling environment can also lend support to pilots through enabling affordable access to finance and offering tax and levy breaks for lime producers.

Liming is a tricky input as it can work to eliminate Al toxicities (for which 10t/ha of lime were needed in the Cerrado of Brazil) and to increase P and Ca availability due to increased pH (for which the type of lime rates we are seeing would suffix). I get the feeling we are dealing with the latter case in most of East Africa, but we are doing further research at the moment to get this right. So, you could also add this as an important knowledge gap that needs further research.

Demand-side interventions

Targeting specific crops with high economic surplus and attractive yield responses to lime is critical to spurring current demand and ensuring a return on investment for farmers. In some of the SAGCOT regions in Tanzania such as Iringa and Njombe, Local Government Authorities and Civil Society Organizations have already begun using demonstration plots for maize to increase awareness of the effects and benefits of lime for farmers. To spur current demand to reach its potential, several bundled solutions which target increased awareness and demonstrate proof of concept for farmers or generate an evidence base for the case for lime will be needed. Notably, these interventions and demonstrations need to be more targeted towards crops that can provide a significant economic benefit to farmers to translate to behavior change and purchase of lime for farmers.

To promote the uptake of lime, increasing awareness of lime, its benefits and application methods for farmers is critical. Interventions focused on raising awareness of lime for farmers in the Lake Zone (where there is low awareness) and coaxing behavioral change for farmers in SAGCOT will facilitate uptake. Demonstration plots, field visits, and fellow farmer (early adopter) testimonials can support behavioral change in farmers who are more hesitant to use lime. These efforts are particularly important in the Lake Zone, given that there is already some awareness of lime in SAGCOT. In the SAGCOT region, lime is primarily used by maize and (commercial medium-sized) avocado farmers in Iringa and Njombe. However, there is a need to scale its use to more regions including Mbeya and Songwe, where there is high potential for economic surplus for farmers.

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

Leveraging private sector models for awareness-raising and streamlining distribution can also support an increase in current demand. Existing lime processors can also play a role in increasing the uptake of lime by partnering with the distributors to provide small quantities of lime for farmers to test and build an evidence base. Suppliers can also map pockets of demand and organize or invest in transportation fleets that can distribute lime to these pockets. Furthermore, with a price-reduction incentive, agricultural marketing cooperatives can also be sensitized to aggregate lime demand from farmers they serve into bulk procurement to facilitate easy access to lime at a reasonable price. For instance, Dodoma Cement offers up

to a 10% discount for bulk purchases (around 200 MT) from farmers, encouraging agricultural marketing cooperatives to band together to purchase lime.[40] Lime suppliers can also partner with development financial institutions to offer experimental lime to farmers through input loan schemes, provided these schemes have low interest rates and longer terms (patient capital) to allow for resource-constrained farmers to invest in them.

Moreover, there is a need to continue soil testing initiatives to ensure that farmers know the quality of their soil to determine whether they need lime, the appropriate rate, and the appropriate application approach they should use. The Ministry of Agriculture has already significantly invested in soil testing equipment through procuring mobile soil testing kits for every council[41] and re-vamping soil testing laboratories in every district.[42] However, these efforts are recent, and substantial farm-to-farm testing initiative by agricultural extension officers will be needed for this to translate to actionable data for farmers. In addition, it is important to note that soil testing results indicating the need to manage soil acidity may not necessarily inspire purchase of lime from smallholder and more traditional farmers who maintain traditional and less effective methods of managing acidity such as by spot treating crops with ashes.

These efforts need to be accompanied by efforts to streamline distribution and reduce the final price of lime for farmers. Given that large amounts of lime are needed to revamp soil acidity compared to other amounts of inputs (such as fertilizers) that farmers are used to transporting, increasing uptake of lime should be done hand in hand with distribution interventions lowering the costs of transportation and storage, and making it easier for farmers to carry lime to their farms. Establishing distribution centers closer to farmers will help ease distribution and access to farmers, reducing transport and logistics costs and allowing for subsequent interventions focused on last-mile delivery to farmers to be implemented. For instance, Dodoma Cement has recently opened a depot for lime closer to farmers in Iringa, which can help alleviate some of the storage costs for lime.

Supply-side interventions

Efforts on the demand-side to increase the uptake of lime should be accompanied by efforts to improve the supply of lime at the required level of quality, quantity, and cost. Achieving sufficient supply to meet anticipated potential demand, requires engaging existing lime suppliers (given that they are operating at subpar capacity due to limited demand) and quarry owners (including cement producers) given that they already have operational experience and have a higher awareness of sector challenges compared to new entrants. As demand increases and suppliers approach full capacity, they can benefit from economies of scale and consider lowering prices to maintain or increase demand. Increased utilization rates for lime suppliers can also encourage the launching of processing plants closer to demand areas (SAGCOT and Lake Zone). Furthermore, cement producers have far-reaching distribution networks that can be leveraged for lower transport costs for lime distribution. Both SAGCOT and Lake Zone regions would benefit from more distribution centers closer to demand areas, as well as lime processing in their vicinity.

Improving production quality requires access to innovative finance instruments. For example, access to patient equity investments or below rate investments to quarry owners and cement producers would allow these actors to invest in (i) processes geared towards improving the quality of agricultural lime and (ii) improving distribution systems. Given the potential economic surplus, traditional banks are well placed to offer tailored products. For example, mezzanine financing options for the lime sector such as concessional debt options for working capital, credit guarantees backed by a third-party to minimize due diligence hurdles, longer-term financing in response to the expected duration to build demand, and alternatives to fixed assets as collateral. Adequate financing in the sector will require capacity building of traditional banks and other financial institutions to develop expertise in agriculture finance allowing them to develop better tailored financial products.

[40] Dalberg, Stakeholder Interviews, 2022
[41] All Africa, Tanzania: Govt to Procure Mobile Soil Testing Kits for all Councils, 2021
[42] Xinhua Net, Tanzania to create soil testing laboratories in all districts, 2021

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

It is important to note interventions to support lime processors should be tailored to individual processors needs to ensure that these interventions have the intended impact. In addition to increasing the quality and quantity of lime supplied, these interventions will reduce the price of lime due to economies of scale and efficiency. This will in turn increase the places where liming creates economic surplus for farmers.

To support linkages between and the expansion of supply and demand, pilot implementation will require concrete solutions carried out by government actors and other partners. Once lime is sufficiently used for the most economically viable or priority crops in the SAGCOT and Lake Zone regions and its effects are experienced, local stakeholders in agriculture will be able to contribute to the promotion of lime as the solution for acidic soils. As understanding of lime builds including its importance in supporting high fertilizer use efficiency in acidic soils, it will spur more lime demand in priority regions. This demand will also encourage an efficient supply of lime and new entrants and competitors in the market, which will lower the price of lime and create a virtuous cycle for demand.

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

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

Private sector

The private sector can strengthen existing distribution for lime in SAGCOT and pilot production and distribution in the Lake Zone by providing finance, streamlining, and optimizing distribution. Commercial banks and other private financial institutions can provide finance to lime suppliers to scale production to meet lime demand in SACGOT and pilot new production capabilities in the Lake Zone closer to farmers in this region. One source of financing that suppliers may be able to leverage is the 20 million USD in loans available through Tanzania Agricultural Development Bank (TADB)'s MOU with African Guarantee Fund for Small and Medium Enterprises.[43] There are lime deposits in the Lake Zone, however, the quantity and quality of the lime in these deposits has not been assessed. In the event that setting a new production plant in the Lake Zone province is not feasible due to quality constraints, finance can be provided to agricultural market cooperatives/ farmers to enable them to afford the increased price of lime due to transport costs. Support to lime producers can enable them to achieve production efficiency, develop supporting infrastructure such as storage closer to farmers, and invest in vertical integration (such as doing their own distribution) to achieve costs savings.

[43] TADB Archives, TADB to Disburse Loans Worth USD 20 Million to Agribusinesses through African Guarantee Fund Partnership, 2021

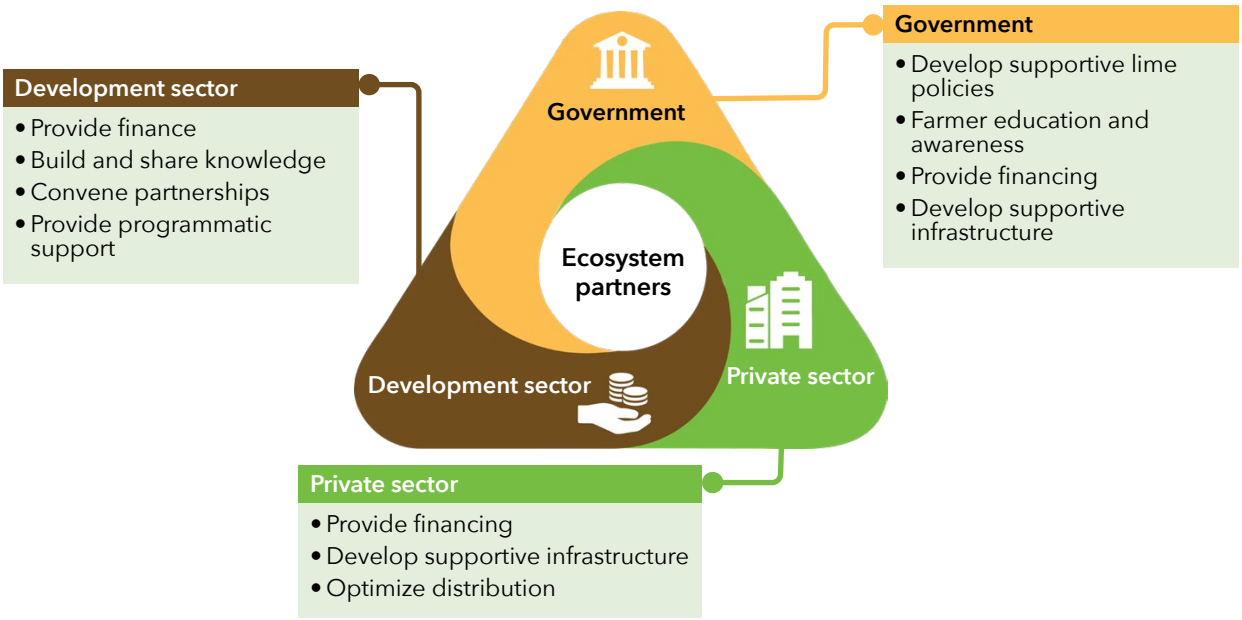

Figure 7: Role of ecosystem partners for successful implementation

Table 6: Examples of private sector actors that can be engaged

Intervention	Examples of private sector players
Lime production	• Existing lime producers such as Dodoma Cement • Cement producers such as Tanga Cement
Provide finance	• Traditional commercial banks such as NMB, CRDB[44] etc, through guarantees and special interest rates for agriculture mandated by Tanzania Agricultural Development Bank (TADB)[45]
Develop supportive infrastructure	• Existing lime producers such as Dodoma Cement and Tanga Cement
Optimize distribution	• Mkombozi Agribusiness

Development sector

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

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

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

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

Government

The government can develop supportive policies and regulations that contribute to increasing awareness of lime and provide support necessary for the supply side. Although the enabling environment in Tanzania has championed the use of fertilizers, little has been said on lime use and managing soil acidity. Greater effort is therefore required to develop concrete policies on lime use and application and lime deposit mapping. These policies should also consider the fees and levies charged for mining of lime and distribution of lime, and how these increase the price of lime. In addition, there is a need to develop standards, specifications, and guidelines for processed agricultural lime to ensure quality lime is produced by all suppliers.

[44] The Citizen, CRDB Bank slashes lending rates to farmers and workers, 2022

[45]

[46] Daily News, Govt Pushes for low agri-loan interest rate, 2020

Nevertheless, the government has recently begun to make initiatives towards understanding soil health through soil testing. These initiatives should be upheld by the government, and agricultural extension officers capacitated to enable accurate soil mapping and data records. Policies that mandate soil testing before the use of inputs (such as presentation of a soil testing certificate before input recommendations are made at the agro dealers') and present lime as a solution to soil acidity can make strides in increasing the awareness of lime. The government can also equip extension officers with the knowledge of how to test soils using procured mobile soil testing devices, and how to train farmers in the use of lime. In addition, the government can launch demonstration plots in each ward as was done in Iringa to provide proof of concept for farmers.

Government support on the supply side can also de-risk private sector investments in the supply chain, reduce costs, and influence the availability and affordability of financing in the lime sector. De-risking private sector investments can be done through public-private partnerships, and guarantees, among others. Moreover, developing supportive infrastructure such as road networks to bring down transportation costs can contribute to the reduction in lime costs. The government is already working on developing supportive infrastructure by improving the railway network. This can continue to be bolstered and improved along with energy infrastructure throughout the country. Examples of government partners that can be engaged include the Ministry of Agriculture (MoA), Ministry of Minerals, Ministry of Works, Transport, and Communications and TANROADS. Through the central bank and Tanzania Agricultural Development Bank (TADB), the government can also push for lower interest rates, for instance, in the agricultural sector.[46]

VII. Conclusion and Next Steps

The insights provided in this report are still preliminary as the data used are at an early stage and continues to be refined by GAIA. More data refinement is needed before large investments by the government and private sector actors can be recommended. However, given a high level of confidence of the economic benefit in the identified markets, efforts on the supply and demand-side should begin to be implemented to build momentum and to validate success before the development of national investments in 18-24 months.

The identified supply and demand interventions are tailored to the SAGCOT and Lake Zone regions to begin building the investment case for lime in Tanzania. Nevertheless, alternative solutions for acidic soil management may be appropriate. Despite the potentially high need for lime from our analysis (about 757,010 MT for key acidic zones and crops with economic surplus), it may be worthwhile considering alternative solutions to acidic soil management. This includes the promotion of non-acidifying fertilizers such as Single Super Phosphate (SSP), Calcium Ammonium Nitrogen (CAN), and Nitrogen Phosphorous Potassium (NPK). This can be achieved by working with fertilizer manufacturers and agro dealers to promote the use of non-acidifying fertilizers and drive awareness among farmers on the effects on acidifying fertilizers on their soils and crop yields. Such efforts can help curb the spread of soil acidity. In addition, wood ash and biochar can be extensively explored as solutions for managing soil acidity. This requires monitoring and evaluation efforts as well as piloting to accurately assess and document the impact of soil acidity management solutions before replicating these solutions to other acidic parts of the country.

Table 7: Analysis of solutions for managing soil acidity

Factor	Fertilizing residual materials (FRMs)	Oyster shells	Acid tolerant seeds	Lime	Wood ash
Soil impact	Neutralizes soil acidity over time	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 country, and imports are expensive	Scarce in African countries - Senegal is the only African country that currently produces oysters commercially. Hence, there is a high likelihood of insufficient supply	Tanzania produces and imports some acid tolerant seeds	There are sufficient lime deposits in the country, however, lime is not sold by agro-dealers and easily accessible by farmers, particularly SHFs	Any burnt wood can be used as wood ash, but due to the large amounts needed it may not be readily available
Cost	High cost due to need for imports	High cost due to 1. Global supply 2. Need for imports	Relatively inexpensive if produced in-country, high cost if imported	Lime is relatively inexpensive (cost of distribution 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	Relatively easy to use compared to alternatives; can be harvested any time of the year	Easy to use compared to soil acidity management methods	Lime in powder 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	Can be sustainably farmed. Oysters purify the water, and act as carbon capturers, sequestering nitrogen and carbon dioxide	May contribute to increasing acidity of the soil	Releases carbon dioxide in processing and also in its reactions with the soil once applied on the farm	Releases carbon dioxide in processing and also in its reactions with the soil once applied on the farm

Given that the adequate uptake of lime largely depends on the ability to prove the actual benefit of lime on crop productivity and hence additional revenue, there is a need for continued research and refinement on crop yield response. Continued research and empirical data derived from the piloting of demand and supply initiatives in the sector and yield response for key crops in the country is critical to building the investment case for lime. In addition, the analysis in this study is limited to the 26 crop yield response data obtained from CIMMYT. This research and refinement should be focused on relevant crops grown in each region of the country and should take into consideration the varying levels of pH and soil conditions to build a robust database. Moreover, current land that could potentially be transformed into cropland (agricultural expansion) necessitating lime should also be considered in the refinement of the data availed. CIMMYT/GAIA can collaborate with other relevant institutions to refine these data.

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

This investment plan should also provide insights on the comparison between lime and other solutions geared towards increasing crop yield and farmer livelihoods. This comparison should focus on the cost for farmers, and effectiveness of the solution in the short and long term, among other factors. This will further unearth the best course of action that provides better returns to farmers while addressing crop yield and farmer livelihoods concerns. These findings can then be presented and validated by key national stakeholders.

VIII. Annex

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

Table 8: List of work packages and documents reviewed

Document	Organization	Description
GAIA ex-ante analysis	CIMMYT	Characterizes the acidic soils in the focus countries
A Review of Agricultural Lime Policy in East Africa: A case of Ethiopia, Kenya, Rwanda, and Tanzania	AGRA	Studies the national policy environment related to agricultural lime in the four focus countries
Tanzania Lime Value Chain Analysis and Report	TARI and CIMMYT	Studies the agricultural lime value chain in Tanzania
AFAP Lime Study	African Fertilizer and Agribusiness Partnership	Examines the need for lime in Tanzania and various challenges
National Sample Census of Agriculture 2019-2020	Tanzania National Bureau of Statistics (NBS)	Evaluates crop production by region
SAGCOT Investment Blueprint	SAGCOT Centre Limited	Provides agricultural details specific to the SAGCOT regions

Table 9: List of Stakeholders consulted

Name	Organization
Theresia Numbi, Marketing Manager	Dodoma Cement (Ag lime producer)
Geoffrey Kirenga, CEO	SAGCOT Centre Limited

Table 10: Summary of some variables related to economic opportunities for lime in SAGCOT and the Lake Zone for key crops.

	SAGCOT	Lake Zone
Average yield response to exchangeable acidity from liming (MT) per ha	0.199	0.374
Lime application per ha	0.597	1.059
Additional revenue within one year (USD) per ha	112.317	205.448
Additional revenue by the third year (USD) per ha	182.697	333.402
Economic surplus within one year (USD) per ha	52.750	99.381
Economic surplus by the third year (USD) per ha	85.656	161.549

NOTES