Market and Economic Feasibility of Granulated Lime in Kenya

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EXECUTIVE SUMMARY

Approximately 13 per cent of Kenya's agricultural land (about 7.5 million hectares) is affected by soil acidity. Acidity presents a significant constraint towards the country's efforts to maximise productivity and achieve food and nutritional security. The high crop potential areas are majorly affected by soil acidity due to continuous cropping, loss of organic carbon, nutrient leaching, and inappropriate use of fertilisers. Soil acidity is primarily improved by applying lime or other acid neutralising materials, which offset soil acidity by raising the soil pH and increasing the nutrients available to plants. Application of agricultural lime is one of the best known and most economically viable soil amelioration and corrective measure against acidity. The required quantity varies for different conditions depending on the soil pH value, quality of the liming material, soil type, farming practices, and rainfall amounts.

Agricultural lime can be applied in many forms, with powder (ground) lime being the most common in many countries, including Kenya. Because of granules cohesiveness, ease of packaging and transportation, and non-dustiness; granulated lime is seen as an alternative to powdered lime because it overcomes challenges relating to bulkiness, dust and difficulty in its application.

Cognisant of the above, this study evaluates both the supply and the demand sides of the Kenyan agricultural lime industry. It assesses the current lime manufacturers, existing products and production levels, and maps out the current supply chain. It also evaluates the current and future infrastructure and investment needs for manufacture of granulated lime, estimates the operational costs and the unit costs for granulated lime, and identifies market size and opportunities for investors in local agricultural lime granulation and distribution. On the demand side, the study estimates the current demand for agricultural lime, availability, products, prices, as well as challenges and preferred form of agricultural lime. It also studies the current awareness levels, use, quantity and value of ground lime demand. The study uses this data to project future demand for agricultural lime and more specifically, granulated lime.

The study estimates the current gap in demand and supply of agricultural lime by studying the two sides and infers the same for granulated lime. A further assessment of the readiness, economic and social feasibility for smallholder utilisation of agricultural lime at farm level; and farm-level economic benefits of using local granulated lime (gross margin analysis), is also conducted. Lastly, the study evaluates the status of the regulatory framework and its ability to support the manufacture and use of granulated agricultural lime in Kenya. The intention was to identify and recommend critical gaps in policy and make recommendations on the same.

A combination of secondary and primary data was used to derive the results presented in this report. Primary data was sourced through a household survey administered in 817 households across 12 counties in Kenya. This was in addition to 20 FGDs and 52 KIIs completed during fieldwork. Enumerators collected household data on CSPro software on Computer-Aided Personal Interviews (CAPI). The analytical framework comprised three fundamental approaches, including a demand and supply analysis, investment appraisals, and economic modelling for farm-level and processing level investments.

On the demand and use of lime, the study found out the following:

- Overall, 59.5% of respondents were aware of agricultural lime. Information on lime was spread through word-of-mouth by fellow farmers and agricultural extension officers. Unfortunately, lime use is still deficient. Despite 59.5% of the respondents being aware of agricultural lime, and 29.3% of these having access to lime, only 20.2% of the respondents reported to have ever used agricultural lime. Notably, 20.2% is a cumulative historical figure; the current lime usage is estimated at about 7%[1]. This means that a majority (79.8%) have never used lime.

- There are information gaps that still limit the use of agricultural lime. Information and knowledge on when and how to apply lime is still unclear. This is mainly caused by mixed messages shared with farmers from various organisations that promote lime use.
  - » Two primary application methods, namely broadcasting and micro-dosing, were noted without a clear view on which was a better application method or when one approach may be preferred to the other;
  - » If and how lime is to be combined with other inputs is unclear. A majority of respondents applied lime separately (17.4%) while a smaller proportion applied lime in combination with other inputs (2.8%), including fertilisers and seeds;
  - » The timing of when to apply lime is also inconsistent. Of the 20.2% that had ever used lime, 8.9% applied lime before ploughing, 3.1% applied during ploughing and 3.5% before planting. An additional 2.7% applied lime during planting time, and 1.9% did it way after planting;
  - » The quantities to be applied per unit area are also unclear. Some studies have recommended that lime be used periodically ranging from every two to three years since lime has residual effects; but only if recommended quantities are applied. Some studies have suggested that about four tonnes of lime should be applied per ha (1.6 tonnes per acre), but also in some cases where micro-dosing is used, quantities used are as low as 0.5 tonnes per acre.
- Sources of lime varied from one region to another, but most of the farmers accessing lime purchased it from the agrovets/ agro-dealers and Farmer Producer Organisations (FPOs). On average, powder lime costs KES 6,000 per MT at ex-factory prices and KES 8,000 for the retail prices. Powder lime is the most commonly used form of agricultural lime; from the study out of those who reported having used lime (20.2%) in their farms, 98.2% used powdered lime (ground lime)[2], and 1.8% used granulated lime.
- Nationally, the primary demand regions for agricultural lime were Central (Mt. Kenya and Aberdares region), Rift Valley (South, Central and North Rift), and Western (Western and lake regions). These demand centres are currently driven by lime use in three key crops: coffee, maise, and sugarcane. Lime use in coffee averaged 336.9 kgs per acre (832 kgs/ha) ranging from a low of 50kgs to a maximum of 2 MT/acre.; while lime use in maize averaged 105.9kgs per acre (262 kgs/ha. Notably, the quantities currently used are still lower than the recommended amounts of about between 2 and 4 tonnes/ ha) under broadcasting application and about 0.5 tonnes/ha under micro-dosing practices[3].
- This study estimates that the current national demand is approximately 187,000 MT annually. The research projects that future need for lime will increase to 319,000 MT in the next five years and then to 532,000 MT in ten years. Key drivers to increased demand would be increased awareness, availability and granulation, improving usability (ease of use) of agricultural lime compared with ground lime.

On the supply of lime, the study found out the following:

- Agricultural lime is currently available in the country but mostly in the powdered form. At least 13 companies are involved in the manufacture and distribution of lime and lime products with two companies being dominant (have the highest market share). The current low demand for lime that is associated with low awareness among farmers is currently the biggest challenge for lime manufacturers;

- The supply channels for lime distribution included manufacturers appointed stockists, independent distributors and retail agro-dealers. Others included NGO projects and programs, coffee cooperative societies, and county government's subsidy programs.
- Currently, the granulated lime market is at the early stages of development, and most of the few importers who deal with this form of lime have commercial trial volumes to test the market. Most of the granulated lime is imported from countries such as Germany and Sweden. According to interview responses on the supply side actors, granulated lime's current market size is estimated at only 4,000 MT annually.
- The potential for an increased market for granulated lime is hinged on its preference as a solution to challenges experienced with ground lime. This is because of its ease of application; it is not bulky and easy to act on specific areas, hence faster working on soil nutrition. Besides, granulated lime has a more long-term effect on the soil than ground (powdered) lime. Further, granulated lime improves the ability to blend lime with other inputs. The lime granules can be mixed with fertiliser granules and applied together with seeds during planting.

On the potential for investments and costs, the following deductions are made:

- At the farm level, additional costs are incurred to purchase lime and to cover for application labour. These additional costs are estimated to be between KES 2,300 and KES 25,500 per hectare depending on the quantity of lime purchased. In comparison, additional costs while doing micro-dosing were relatively low. Broadcasting lime attracts at least three times higher costs than micro-dosing; which is done together with planting and fertiliser application.
- It was challenging to establish the actual contribution of liming on the achieved crop yields. Most of the farmers who applied lime in their farms combined it with inorganic fertiliser and organic manures. Majority of smallholder farmers do not maintain data on their lime use or even when and where they applied. Thus, they are unable to quantify the change in yield as a result of lime application. Previous studies have estimated that yields in maize can increase by between 10 to 20%.
- The study showed that maize yields increased by up to 62.9% per acre when lime is applied versus when lime is not applied. Based on results achieved, it is clear that an increase in lime use in the areas with acidic soils would significantly increase the country's production. In effect, a policy shift to encourage the use of lime in agriculture areas would spur the agricultural lime industry's growth as farmers will be encouraged to use lime due to increased benefits from the improved production.
- For maize, economic returns were higher where lime is applied by micro-dosing. This is attributed to low amounts of lime used, and thus low costs for purchasing lime and minimal application costs, as lime is applied together with fertilisers and seed while planting. In coffee, the benefit/cost ratio was higher for farmers using lime than those that were not using it; despite the additional costs for purchasing and applying lime. Even in the short run, coffee farmers who apply lime would get six times more revenues than the costs incurred. In the short run, potential benefits will be at least 1.64 times higher than the costs incurred increasing to 2.01 times in the long run.
- On the supply side, it was noted that lime granulation investments would require at least KES 58 million for a 15 MT/hour granulation plant and KES 148 million for a 50 MT/hour plant. With the projected

increase in demand, such investments will attract positive returns and payback in 2.63 years for model 2 and 4.98 years for model 1.

- Additional benefits from local granulation include foreign exchange saving and lowering of prices of granulated lime. Where granulated lime is locally produced, the country would save USD 2.07 million per annum. Local production would also see the cost of granulated lime drastically drop from KES 2,800 to as low as KES 650 per 50Kg bag. Local production would also create jobs for the numerous unemployed youth in direct and indirect employment in the extraction, transportation, processing, packaging, and distribution of the granulated lime produce.

On policy limitations, the study found as follows:

- The lime industry's key policy challenge is the lack of clear and quality guidelines and agricultural lime standards. The presence of many lime products and blends have created weaknesses in the availability of standard products to both small-scale and large-scale farmers. Many lime products lack standardisation especially on their purity (CCE) and the particle size of the liming material (which can help in volume conversion between different products)
- Overall, there is a low investment by both public and private sectors in awareness creation. There lack a nation-wide awareness creation platforms and funding opportunities. For example, there is low public awareness in comparison to fertilisers, and both national and county governments do not have set guidelines for lime subsidies.

Recommendations from the study

On farmer awareness:

- Efforts should be made through and by various stakeholders – national government, county government, donor community, private sector and other players – to increase general awareness of lime and granulated lime and stimulate demand. Information on the timing, application methods, required quantities, and yield responses need to be researched and documented.
- There is need to increase awareness on soil health and nutrition, use and benefits of powdered and granulated lime use. The government subsidy programme should also be enhanced by including soil improvement products that farmers can easily adopt. Among the essential products to be promoted would be lime.

On lime production, supply and distribution:

- Consideration should be made to granulating lime through a decentralised arrangement to reduce transport costs and to be able to utilise lime from existing manufacturing plants.
- There is a need to develop standards on quality at the market and quality level for granulated lime. Kenya Bureau of Standards needs to work with industry players to establish parameters necessary for categorising the lime products in the market.

On policies:

- There is a need to develop an enabling policy to incentivise development and investment in local granular lime production. Investors might fear the current low demand and usage as the initial returns might be marginal.

1

INTRODUCTION

1.1 About the report

This report comprises findings of a study conducted by Kenya Markets Trust (KMT) in 2020. The study entitled "Market and Economic Feasibility for Granulated Lime in Kenya" assesses the Kenyan granulated lime market and its economic viability by estimating the supply, demand, costs, and returns/benefits at the critical value chain nodes including at the farm level, distribution level and manufacturing level.

1.2 Rationale for the study

Acidic soils, those with a pH value lower than six, have become a significant challenge to farmers in Kenya. This is particularly so in maize growing areas, especially those traditionally regarded as the 'breadbasket' of Kenya. Soil acidity associated with Aluminum toxicity and nutrient deficiency affects crop growth and limits agricultural productivity (yields per hectare).

According to the Kenya Agricultural and Livestock Research Organization (KALRO)[4], acidic soils cover about 7.5 million hectares (19.1 million acres) nationally, which makes up about 13% of Kenya's arable land. The most affected regions are in the Lake Basin, Western, North Rift, Mt Kenya, Aberdares, and the Coastal regions. These areas, therefore, formed the locus of this study.

Recommendations to ameliorate soil acidity include lime use, non-acidifying fertilisers, and soil organic carbon build-up. The application of agricultural lime reduces soil acidity, improves nutrients available to plants and enhances root growth. Lime use, coupled with good agricultural practices, can therefore significantly improve crop productivity for smallholder farms.

To test the impact of lime on crop productivity and soil acidity reduction, KMT piloted a project in four (4) counties in Western Kenya. The key objectives for the pilot project were:

1. to enhance awareness on soil acidity;
2. to improve access to agricultural lime through the commercial distribution chain
3. to enhance strategic partnerships for soil testing and extension services

As part of the pilot, KMT conducted agro-dealer training on customer care and business management; radio promotion to enhance awareness; on-farm demonstrations and field days to showcase lime's impact on acidic soils; and the improvement of brand awareness and packaging. Key project achievements in the four pilot counties included: the establishment of four distributors with 60 agro-dealers (stockists); and over 50,000 farmers availed with information on soil acidity and liming; and 15,000 farmers bought agricultural lime which resulted in over 50% increase in maize productivity (KMT 2019[5]).

Despite potential increases in agricultural productivity, an impact assessment on the pilot project conducted by KMT in 2019, noted that the current supply, demand, distribution and use of lime was limited. The commonly used ground lime was noted to be bulky, difficult to apply and dusty, attributes that limited its usability on the demand side. Additionally, whereas there is an emerging demand from smallholder farmers, for granulated lime, there is insufficient information/ data on the current availability, distribution, utilization and productivity effects of granulated lime, as well as the economics of its production and sale.

Therefore, this study was commissioned to determine the factors that will make the lime granulation business successful by analysing the market and the economics of granulated agricultural lime in Kenya.

1.3 Objectives and scope of the assignment

In addition to acquiring a rounded understanding of the granulated lime market in Kenya, the main objective of the assignment was to assess the market and economic feasibility of granulated lime in Kenya by assessing the supply, demand, costs and returns/benefits at the critical value chain nodes, including at the farm level, distribution level and manufacturing level.

The study starts by understanding and characterising both the current demand and supply of lime and potential market for Kenyan granulated lime (both the supply and the demand sides), and goes a step further to estimate the essential infrastructures required for lime manufacturing. It also estimates the investment required to manufacture granulated lime in Kenya.

The report assesses the readiness, economic, and social feasibility for smallholder utilisation of agricultural lime at farm level on the demand side. By attempting projections for future demand and supply of granulated lime, the study estimates the timeline for the development and take-off of Kenya's agricultural lime market. It also identifies the barriers and challenges that could undermine its local manufacture and use in Kenya. Eventually, the study assesses and estimates the potential for economic growth and return on investments for local manufacturers, retailers and users.

Further, the study assesses the policy, legal and regulatory readiness for large-scale manufacture and use of agricultural lime in Kenya. The results from this assessment are used to develop a policy brief on Kenyan agricultural lime. Ultimately, the study generates suitable and practical recommendations on the way forward for Kenya to adopt in the local manufacture and use of agricultural lime.

2

PRELIMINARY REVIEWS ON AGRICULTURAL LIME

2.1 Agricultural Productivity and Soil Acidity

Farm-level agricultural productivity is affected by various challenges. They include limited access to quality inputs, low extension support, slow adoption of improved technologies, and soil degradation (FAO. 2017; Bekabil, 2014). According to KARLO (2019), yields for common crops such as maize have stagnated at around 1.7 MT/ha for smallholder farmers than some commercial farmers who achieve between 10 to 15 MT/ha while yields for beans range between o.3MT/Ha to 0.5mt/ha. To increase crop productivity, smallholder farmers often tend to increase the use of fertilisers. According to KALRO (2018), the use of fertilisers increased by 25% between 2014 and 2016. According to the Ministry of Agriculture (2018), the most commonly used fertiliser is Di-Ammonium Phosphate (DAP).

Even though the current average fertiliser use of 30kg/ha, falls far below the 50kg/ha recommended by the Abuja Declaration of 2006, nitrogenous fertilisers such as DAP have mostly resulted in acidic soils[6]. Soil acidity also increases with heavy rainfall and leaching, use of ammonium-based fertilisers, acidic parent material, soil erosion and organic matter decay. Soils with a pH level below seven are considered acidic while those above a pH of 7 are basic or alkaline. According to Kanyajua et al. (2002), soils can be classified as alkaline, near neutral (pH of 6.5 to 7.0), slightly acidic (pH of 6.0 to 6.5), moderately acidic (pH of 5.0 to 6.0), strongly acidic (pH of 4.5 to 5.0) or overly acidic (pH below 4.5).

Different crops have different tolerance levels to soil acidity. On average, crops require a pH range of 6.0 – 7.0 for optimal growth. Chillies, sweet potatoes and Irish potatoes are tolerant to acidity and can do well in soils with pH values below 6. Most of the horticultural crops (onions, spinach, carrots and cabbages) do not tolerate acidity and can only grow well in soils with pH values of 6.2 – 7.4. Other crops like maize lie in the medium tolerance range and would do well in soils with pH values of 6.0. The critical threshold of soil acidity is 5.5, below which aluminium becomes toxic to plants. Optimum soil pH is around 6.5. At this pH, aluminium is no longer toxic, and other soil nutrients become available for uptake by plant roots. Acidic soil severely impacts on crop productivity. As hydrogen ions increase in the soils, their ability to release essential nutrients for soil growth is inhibited. At low pH levels, calcium, phosphorus, potassium, magnesium and molybdenum may become deficient, while at high levels above 7.0, iron, manganese, zinc and phosphorus may become deficient.

Information synthesised from the Kenya Soil Health Consortium (KSHC)[7], reveals that numerous efforts have been made to counter soil acidity in Kenya including the application of lime, use of organic materials, and breeding crop varieties tolerant to acidity. However, amelioration of acidic soils has not received much-needed attention. As a result, land areas previously covered by acidic soils has drastically increased within less than a decade (Kanyanjua and Ayaga, 2006; NAAIAP, 2014). Soil acidity is mainly ameliorated by applying lime or other acid neutralising materials. Acidic soils occupy 29% of the total land area of sub-Saharan Africa (SSA) zone and 13% of Kenyan land area[8].

In comparison, an estimated 15% of all agricultural soils in Africa are affected by soil acidity[9]. The Western Kenya region, the Lake Region, and Central Kenya are the most affected by soil acidity. The Ministry of Agriculture estimates that around 50% of smallholder farms in Western Kenya have soils with pH values below 5.5 (One Acre Fund Report, 2016).

A mapping exercise for acidic soils conducted by KARLO (2002) noted that three major soil classes in Kenya that are mainly affected by acidity include Nitisols, Acrisols and ferralsols. These soils are found in Kisii, Migori, HomaBay, Siaya, Busia, Bungoma, Kakamega, Kericho, Narok, Uasin Gishu, Elgeyo Marakwet, Baringo, Murang'a, Nyeri, Embu and Meru Counties

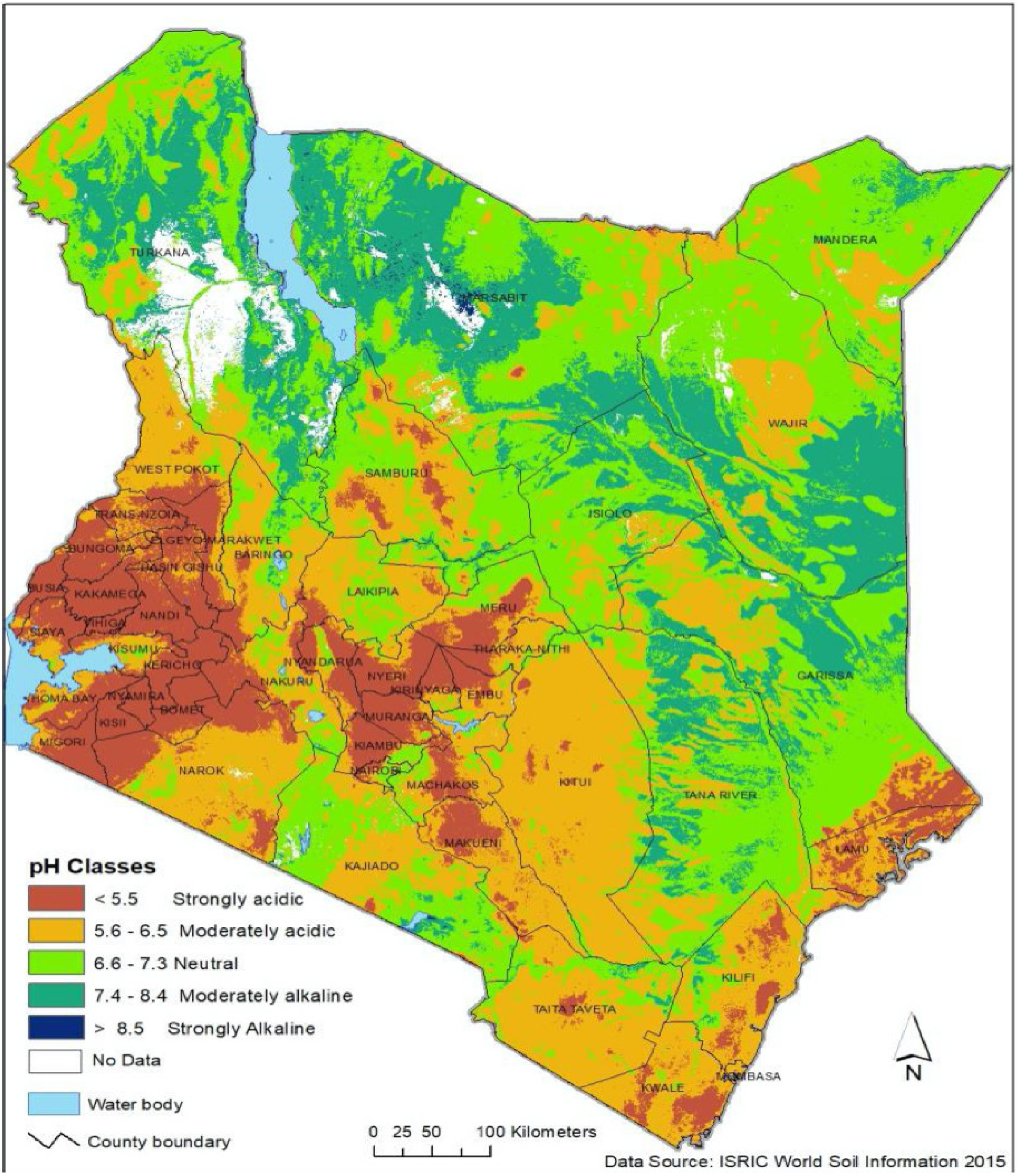


Figure 1: A map of Kenya showing sub-counties affected by soil acidity

Source: CN Kibunja, EW Gikonyo, SK Kimani, LW Mbuthia, AO Esilaba and D Kamau, KeFerT-Conference-Proceedings, 2018

(Figure 2-1). Most of these counties' areas have soils with pH levels less than the critical threshold of 5.5, meaning that they can be classified as moderately acidic, strongly acidic or extremely acidic. These affected regions form the food basket of the country. Thus, acidity poses a significant threat to Kenya's food and nutritional security.

The use of different volumes of granulated lime has been investigated in Kenya[10]. Two experiments were conducted; a glasshouse and a field experiment. Treatments for the glasshouse experiment comprised of granulated CaO.MgO lime at four levels (0, 2, 4, 6 t/ha-1) and P-fertilizer at four levels (0, 30, 60, 90 kg P ha-1). The field experiment treatments comprised three lime materials (Calcium carbonate, calcium oxide and granular CaO.MgO lime) and fertiliser. This study found that the combination of CaCO3 lime and fertilisers was the most consistent in ameliorating acidic soils.

Internationally, a study was commissioned in Iowa in 2014 to assess usage of different types of lime[11] outside Kenya. Six field trials were established in acidic soils (pH 4.9-6.1) with contrasting texture and organic matter. Treatments replicated three times were commercially-available finely ground CaCO3, calcitic ag-lime, and pelleted lime. The study concluded that pelleted lime was as effective as powdered CaCO3 at increasing soil pH.

2.2 About agricultural lime

Agricultural lime[12] is a soil additive made from pulverised limestone or chalk. The primary active component is calcium carbonate. Of the various agricultural liming materials used to manage soil acidity, calcium carbonate is the most effective with a neutralising value of 100%, followed by dolomitic lime[13]. Agricultural lime comes in magnesium or calcium forms and several states: oxides, hydroxide, silicate or carbonate. Calcium and magnesium on their own will not neutralise the pH level. Only when applied in these forms, will they serve the purpose of lowering acidity levels[14].

Agricultural lime is used to increase the soil pH through combination with hydrogen ions present in the soil to neutralise toxic elements and decrease plant availability of elements such as aluminium and manganese which can be toxic to plants. Lime also increases the nutrients available to plants; adds calcium and (or) magnesium to the soil, and improves the environment for beneficial soil microorganisms. These microorganisms promote the rapid breakdown of organic materials in the soil, releasing nutrients for optimal crops growth. Liming also promotes nodulation by nitrogen-fixing bacteria in leguminous crops[15].

The key benefits of agricultural lime include:

Raising soil pH, improving the soil properties and nutrients available to the plants as it improves the availability and uptake of major plant nutrients (nitrogen, phosphorus, magnesium and potassium) of plants growing on acid soils;

- Promoting better nitrogen fixation by legumes;
- Reducing toxicities in the soil (Reduces Aluminium (Al) and Manganese (Mn) toxicities);

- Enhancing the effectiveness of some herbicides and fertilisers;
- Improving the soils ability to store water and permits improved water penetration for acidic soils; and
- Promoting crops root development.

2.3 Agricultural lime in Kenya

The main types of agricultural limes in the Kenyan market are calcitic lime - calcium carbonate ($CaCO3$) and dolomitic lime ($CaCO3.MgCO3$ or CaMg ($CO3$)2. In addition to containing calcium carbonate, dolomitic lime also contains a mixture of magnesium carbonate and is recommended in soils deficient of magnesium (Okalebo et al.,2009; One Acre Fund Report, 2016; KMT 2019).

In Kenya, lime is available in large limestone deposits found at various sites including; Homa Lime Company and Athi River Mining (ARM)-Mavuno Fertilizers Company.

Arguably, agricultural lime is derived from the least quality of limestone after extracting products such as hydrated lime (Calcium hydroxide). More than 20 different agricultural lime products are available from at least eight local companies in Kenya. The agricultural lime is processed and marketed in the following forms:

- Powder form – crushed limestone into powder/chalk form and packed in 50kg bags.
- Granulated form – crushed/powder lime is processed into granular form for easier field application; and
- Liquid form – The lime is suspended in liquid form for instant activity in the soil and can be applied on already growing fields.

Even though there are several sources and types of liming products in Kenya, most of it is available as ground lime or powder form. Consequently, powdered lime is the most used form of agricultural lime.

2.4 Challenges in agricultural lime use and marketing in Kenya

An impact assessment of the lime pilot project in Western Kenya[16] conducted by KMT (2019), highlighted various lime use challenges in Kenya. A primary challenge was the limited knowledge or awareness of lime among resource-poor farmers who had limited resources to purchase lime. Others included insufficient information on the available products, and weak collaboration between the market actors and manufacturers, extending to the distributors and the stockists. Overall, low demand resulted in low incentives for the manufacture and marketing of agricultural lime. This implies that the agricultural lime sector in Kenya has remained small.

While the current low lime usage may be attributed to the above and several other factors, the powdered form of lime commonly available is thought to be the significant challenge for current users. This form is often bulky, difficult to apply and dusty. As a result, farm-level use of ground lime, especially among smallholder farmers is limited.

While the actual lime is not costly, the high cost of transportation and distribution prevents lime from being affordable, especially to smallholder farmers. Further, the quantities of lime required to change the soil pH significantly are large and at times, practically impossible for smallholder farmers to access.

According to a report by One Acre Fund (2016)[17], common lime recommendations are often in tonnes per hectare[18], several times greater than other inputs (e.g. seeds and fertilisers), required only in a few kilograms per hectare. Research conducted by KSHC in 2014 and AGRA in 2013, on maize grain yields and benefits-cost analysis comparing lime and soil health inputs in Western Kenya, indicated that the best results and highest profit were obtained from liming at four tons per hectare.

Other challenges relate to the lime application, with farmers noting that powdered lime is dusty, difficult to apply, and labour intensive; further increasing costs.

Additionally, the KMT (2019) impact assessment of the liming pilot project highlighted some of the key challenges towards the expansion of the lime market and use of lime by farmers which included the following:

- Many farmers still expect government and donor agencies to help them acquire lime,
- Farmers perceive lime application as a bulky and costly process,
- Some farmers due to limited knowledge on liming end up mixing lime and fertiliser during planting; and
- There lacks a national policy on lime manufacturing, distribution, subsidisation, and use

The above challenges imply that while there is a great need to educate farmers on agricultural lime availability and use, there is also need to avail lime in a more user-friendly form (such as a granulated form). The lime application process should also be more farmer-friendly and cost-effective.

2.5 A comparison of agricultural lime with the fertiliser sector in Kenya

The lime industry in Kenya is almost comparable to its fertiliser industry. Kenya imports almost all her fertiliser requirements, most of which (70%) arrives as bulk cargo (not bagged). As at December 2018, fertiliser consumption in Kenya was estimated at 800,000 MT of 68 fertiliser types. Out of this, imports were approximately 626,420 MT valued at US$233.12 (Africa Fertilizer.org 2018[19]; Oseko E and Dienya T. 2015).

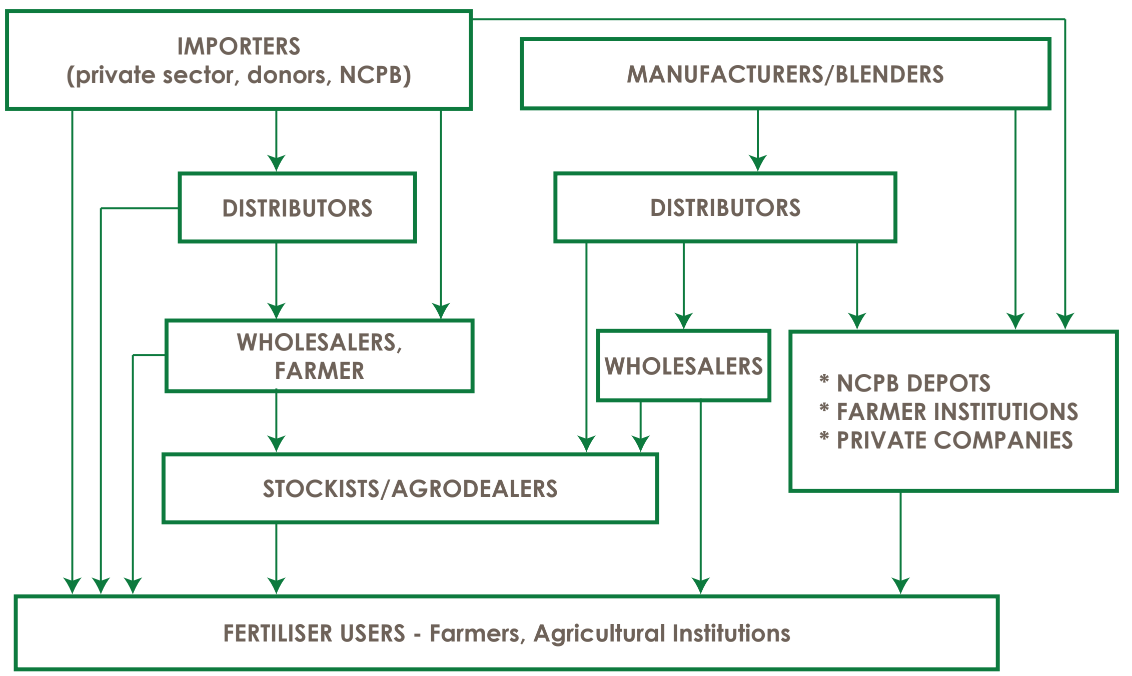
In contrast, while Kenya manufactures most of its locally-used ground lime, only a limited amount of fertiliser is manufactured locally[20]. Local fertiliser blending in Kenya is done by MEA Limited, Export Trading Group (ETG), Athi River Mining

(ARM), and Toyota Tsusho Fertilizer Company in their Eldoret plant. Most of these companies have an annual installed capacity of 150,000 MT (of different fertiliser blends), but the utilisation is less than 50,000 MT.

The blends from these companies are either soil or crop-specific. For example, blends from ARM, popularly known as Mavuno fertilisers, contain eleven elements, including trace elements. The feedstock for fertiliser blending is imported while other materials are found locally. The imported materials include Di-ammonium Phosphate (DAP), Murate of Potash (MOP), Urea, and trace elements such as Zinc, Manganese, Copper, Boron and Molybdenum. The locally available materials used in blending include Gypsum and limestone (Mathenge M.K 2009; Oseko E. and Dienya T. 2015). It is also notable that some fertilisers can be blended with lime capabilities[21].

There exist well laid-out distribution channels in the fertiliser sector. Once the fertiliser is imported, it is then bagged and distributed along any three main fertiliser distribution channels. The first channel type is the commodity-based interlinked input-credit-output marketing systems typified by the Kenya Tea Development Agency (KTDA) and One Acre Fund fertiliser distribution models. In this system, farmers, especially smallholders, are given credit in the form of physical farm inputs purchased in bulk by supporting an agency that distributes the fertiliser to registered farmers. The second fertiliser distribution system involves a network of private, independent importers, wholesalers, and retailers operating on a demand and supply basis. Distributors in this system are estimated to be about 8,000 agro-dealers working with about 3,000 wholesalers and retailers. The third distribution category involves Government procurement of fertiliser and distribution and sale of fertiliser to targeted needy farmers at subsidised prices under the fertiliser price stabilisation plan. Under this arrangement, governments distribute fertiliser to farmers through NCPB, which has 65 NCPB depots countrywide. The figure below shows the fertiliser distribution channels in Kenya (Tegemeo Institute, 2010).

Figure 2: Fertiliser marketing chain in Kenya



Regarding the forms of fertilisers, granulated fertilisers are the most common although there are other forms of inorganic fertilisers, such as solid and liquid fertilizers. This contrasts with agricultural lime which is commonly found in powder form[22]. Compared to the other forms of lime, granulated agricultural lime has various benefits including:

- *Ease of handling and use*. Granules are often dry and compact making them easy to handle and apply.
- *Odour free*. Most granulated fertilisers are odourless thus less offensive during application
- *Convenient and longer storage*. Granulated fertiliser are easy to package and store. Granulation also reduces moisture absorption, enabling fertiliser to be stored for longer periods of time while retaining its useful properties
- *Easy to transport*. The fact that they can be conveniently repackaged, makes it easy to transport. The odour-free nature and the fact that granulation assumes a simple form reduces bulkiness and improve transportability.
- *Less dusty*; compared to powders, granules are almost dust free
- *Less harmful to soils*. The process of granulation often uses heating of the dried or powdered fertiliser. The aspect of heating often kills pathogens and foreign matter such that the resultant granules are cleaner.
- *Allows compounding*. Granulation of fertiliser products provides some of the most viable ways to blend minerals to create a multi-nutrient fertiliser (compound fertilisers).
- *Ease of mechanisation*. It also allows it application to the farm to be mechanised owing to ease of application.

With regards to policy, the fertiliser sub-sector in Kenya is not regulated under one comprehensive/specific legislation. Instead responsibilities for various aspects relating to fertiliser manufacture, marketing and trade are vested in several statutes. These pieces of legislation include the Fertilizers and Animal Foodstuffs Act (Cap 345 of the Laws of Kenya), Weights and Measures Act (Cap 513), the Standards Act (Cap 496), and the Finance Act.

3

METHODS AND APPROACHES

3.1 Overall approach and analytical framework

Overall, the assignment comprised an analysis of two key components, i.e. market feasibility and economic feasibility analysis.

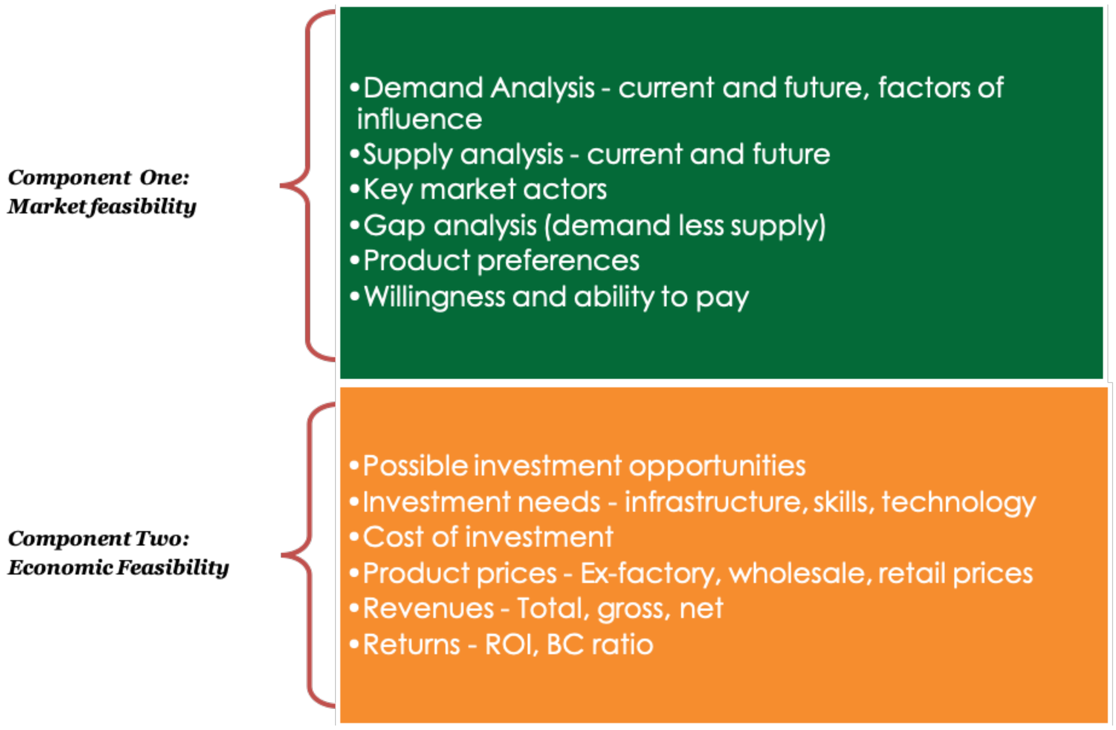


Figure 3: Key areas of the analysis

The market feasibility analysis included the following aspects:

- **Lime demand analysis:** This involved analysing the awareness levels of agricultural lime among farmers, determining the current use and volumes demanded, the potential and projected demand volumes per annum, the factors influencing existing demand and future demand, the key demand centres/regions, determining farmer preferences, ability and willingness to pay for agricultural lime (especially granulated lime), and the perceived benefits derived from lime application.
- **Lime supply analysis:** This involved determining the key manufacturers nationally, the current form of lime sold (liquid, powdered/ground, granulated), quantities of both ground lime and granulated lime manufactured locally, quantities imported, intermediaries in supply (distributors/stockists/agrovets), current packaging and packaging quantities, lime manufacturing and distribution costs, and the ex-factory prices.

The economic viability analysis focused on the following levels:

- **At the manufacturing level:** After determining the existing gaps, possible investment opportunities and the number of viable business units were determined. For a typical manufacturing business unit, the sizing and the location (determined as per the demand centres and service areas), investment and operational costs specifically for a granulated lime plant, raw material sources, production capacities, sales volumes, ex-factory prices, labour and technical skills requirements, gross margins and the profits were also estimated. A presentation of the cost structure of granulated lime production was generated for a single business unit and a production unit (a ton of granulated lime). This was done while comparing the cost structure and margins for granulated lime with that of ground lime.

- **At the marketing and distribution levels:** The report modelled a typical lime distribution business based on volumes handled; determined the number of viable business units based on the manufacturing capacities and demand; the infrastructure required for distribution, including transportation and storage; the investment costs and operational costs for setting up the business; the wholesale prices, volumes sold and the revenues generated. After this, an economic analysis was undertaken.
- **At the farm level:** A double-layered analysis of planting with lime and without lime or before using lime and after using lime was undertaken. To achieve a reliable outcome, a comparison was made for farmers cultivating a similar crop under a standardised land area (i.e. per acre or hectare per season). Critical aspects for comparison included production costs (including or excluding lime), yields per season per hectare, the price of lime, and revenues per hectare per season.

In addition to the two components above, a review of the policy and regulatory framework was undertaken. This included an analysis of the existing policies and regulatory framework that govern and regulate the production, distribution, sale and use of agricultural lime, and how they affect the businesses and the farmers.

3.2 Data needs, types and sources

The results included in this study are based on both qualitative and quantitative data sourced from primary and secondary data sources. Secondary data was complemented with field surveys by interviewing lime manufacturers, traders and farmers. Eventually, empirical findings were triangulated with previous studies done around agricultural and more specifically, granulated lime.

Key data needs differed depending on the targeted respondents and the data types. Secondary data sources included reports on manufacturing, distribution, imports, usage and economic benefits of agricultural lime in Kenya. These provided existing data on the market potential for agricultural lime, the economic potential of granulated lime and comparable markets in the agricultural sectors. Primary data was sourced from identified respondents, including lime manufacturers and distributors, lime retailers/agrovet shops, and smallholder farmers.

Other respondents included key informants from county agricultural departments, research organisations and soil testing organisations. Stakeholders relevant in the inputs sector like KALRO, AGRA, IFDC, One Acre Fund, universities and industry regulators at the national and county level were also interviewed.

3.3 Data collection approaches

3.3.1 Literature reviews

Secondary data was collated through comprehensive review of relevant reports from Kenya Markets Trust, government agencies and relevant stakeholders. Target data was on agricultural production, manufacturing, trade and use of agricultural lime, especially from key stakeholders and research organisations.

3.3.2 Primary data collection and sampling approaches

Primary data was collected through three (3) key approaches, namely: a household survey; Key Informant Interviews (KIIs); and Focus Group Discussions (FGDs). Apart from the smallholder farmers, who were randomly selected within the targeted wards, the rest of the respondents were purposively selected based on the role they play (or have previously played) in the Kenyan agricultural lime value chain. For each of the sub-categories, a Key Informant Interview guide was used to collect data using face-to-face interviews.

3.3.2.1 Key informant interviews

Respondents for KIIs were purposively selected and targeted depending on their roles in the agricultural lime sector. The KIIs targeted the following respondents.

- *KMT staff* – Key staff in the policy and inputs sector. Two interviews were completed with KMT staff.
- *Lime manufacturers and or importers* – An initial list of 10 agricultural lime manufacturers were identified at the Inception stage. Out of these, three respondents were interviewed. The list of the key manufacturers, importers and traders targeted is attached as Annex 8.4.
- *Agro-dealers and lime stockists* – These were either purposively or randomly identified at the county level. Sixteen agro-dealers/stockists were interviewed as part of the study. The list of agro-dealers /stockists is attached as Annex 8.4.
- *Coffee cooperatives* – During pretest, coffee cooperatives were identified as key players in lime supply, especially in Kirinyaga, Nyeri and Murang'a Counties. Consequently, three coffee factory managers were interviewed as part of the key informants.
- *Extension services providers* – These mainly comprised staff from the county departments of agriculture and targeted county, sub-county and ward agricultural officers. A total of 22 staff were interviewed from all the 12 counties sampled. The list of interviewed county officers is attached in Annex 8.4

- *Research organisations and universities* – Researchers from key organisations, including KARLO and universities were targeted. Five staff were interviewed altogether, with three being from KARLO and two from universities.
- *Soil testing organisations* –Four (4) key research and soil testing organisations were initially identified. These included KALRO-Kabete, Crop Nutrition Laboratory Services (Crop-Nut), Soil Cares Limited and Moi University (soils department). Out of these, three interviews were conducted.
- *Organisations promoting lime use* – Four (4) organisations were initially identified based on their previous involvement in the lime (or related) sectors. These included One Acre Fund, IFDC, AGRA, and FIPSs Africa. Out of these, three respondents representing three organisations were interviewed.
- *University Researchers* – Apart from researchers from KALRO, two (2) interviews were conducted with researchers (soil fertility specialists) from two universities namely Rongo University and Pwani University

3.3.2.2 Producers – Focus Group Discussions

A total of 24 FGDs were targeted (two in each county). Each FGD comprised of between eight to 12 (average 10) participants and considered equal gender representation. Eventually a total of 20 FGDs were held.

3.3.2.3 Producer households' survey

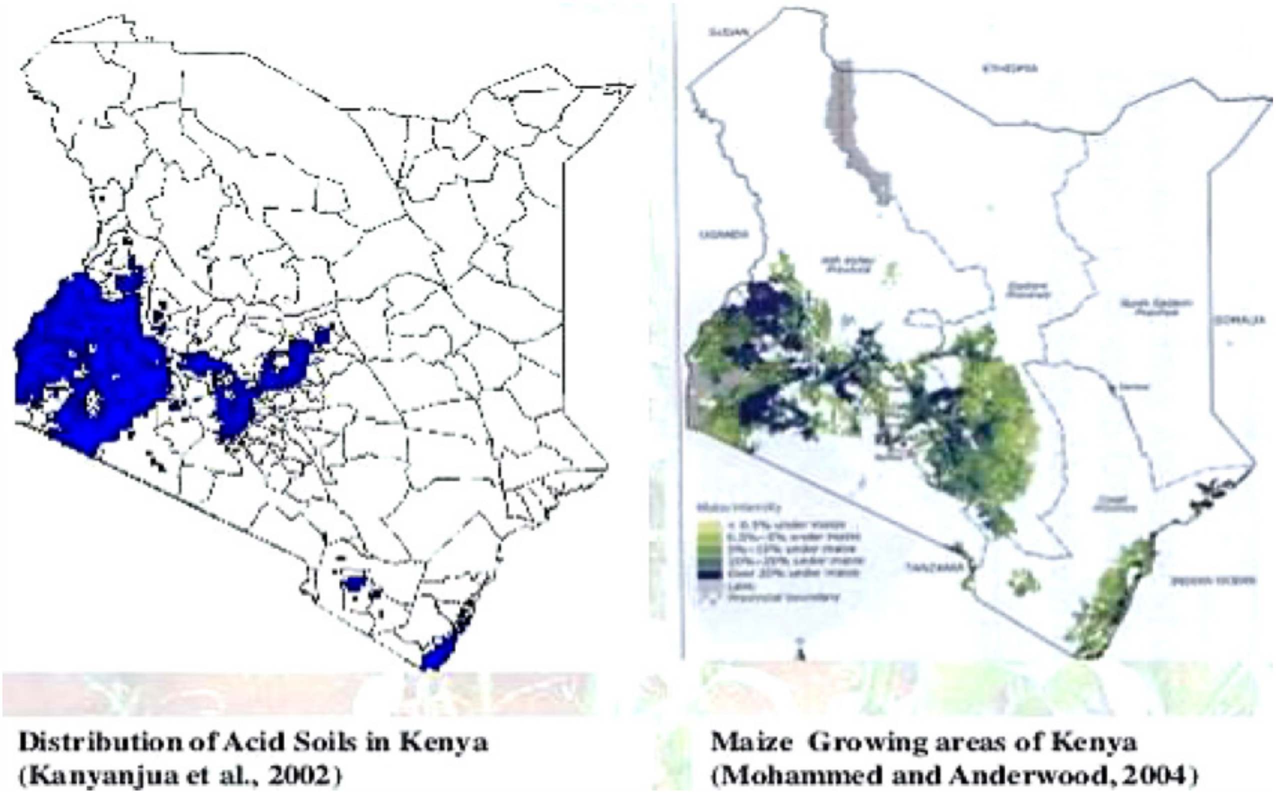
A household questionnaire was developed to collect data from household respondents. This tool was uploaded on a CSPro platform and data collected using Computer-Aided Personal Interviews (CAPI).

A multi-stage sampling approach was used for targeting smallholder farmers across the identified counties. As a starting point, information from KARLO was used to determine regions highly affected by soil acidity (Figure 3-2). Considerations also included the main maize growing areas, thus food security implications. The regions most affected by acidic soils were determined as the Lake basin, Western, North Rift, South Rift, Mt. Kenya, Aberdares and the Coast.

Within each of these regions, 12 counties were selected. These were selected based on whether and how widespread soil acidity has previously been recorded. At least one representative Sub-County was then selected based on their contribution to acidic soils within the county as well as their diversity in the crops produced and their role in food crops production.

Figure 4: Distribution of Acidic Soils and Maize Growing Areas in Kenya

Source: Kanyanjua et.al 2002 and Mohammed and Anderwood, 2004



Within each Sub-County, a representative Ward was selected within which respondents were drawn. In some cases, guidance about which sampling villages were appropriate was guided by the Ward Agricultural Officers (WAOs). Households were then randomly selected within the identified villages. Within the households, key decision-makers,' i.e. the head of the household or the spouse were the target respondents. In case of non-availability of select households, these were replaced by selecting the next household that had not been selected to participate in the study.

Figure 5: Study areas

REGION	Coast	Mt Kenya	Aberdares	North Rift	Western	Lake Basin	South Nyanza
County	Kwale	Meru, Kirinyaga	Muranga, Nyeri	U. Gishu, T. Nzoia	Bungoma Kakamega	Siaya	Bomet, Nyamira
Sub County	Msambweni	Buuri, Kirinyaga Central	Mathioya, Mukurweini	Turbo, Kiminini	Kimilili tongaren, Lugari	Ugenya	Sotik, Borabu
Wards	Ramisi	Kisima, Mutira	Gitugi, Mukurweini Central	Kiplombe, Waitaluk	Kamukuywa Lwandeti	Ugunja	Rongena, Nyansiongo
Target Crop	Maize, Horticulture	Irish potatoes, Wheat, Coffee, Horticulture	Coffee, maize, beans	Maize, wheat	Maize, beans, coffee	Rice, maize	Maize, beans, tea

3.3.2.4 Sample size determination for smallholder farmers

The sample size for the smallholder farmers was determined using Fischer's et al (1998) formula. This formula was selected as it provides an option for estimating sample sizes when the target population is infinite.

$$n = \frac{z^2pq}{d^2} \quad \text{...Equation 1}$$

Where n = Sample Size

d = the level of precision

Z = the Z score corresponding to the confidence interval

p = Estimated proportion of producers in the population

q = 1-p

Given a 97% Confidence interval, with a +/-3% level of precision and a p value of 75%, the resulting sample size is determined at:

$$n = \frac{1.88^2 \text{ x } 0.75 \text{ x } 0.25}{0.03^2}$$

n= 736.3

n ~736

Therefore, the sample size n was determined as 736 Respondents. It was also adjusted upwards by 10% to cater for non-responses making a total of 809 respondents. Eventually, a total of 817 interviews with household respondents participated in the survey.

3.4 Data analysis approach

Quantitative data was uploaded onto data analysis software (STATA and SPSS as applicable) to generate the desired statistics. An analysis of productivity changes, especially before and after lime application, was tested using a one-way ANOVA test to test for significance across the means (t-test), especially of productivity for those using and those not using lime. The data was disaggregated by counties, gender or age, as deemed appropriate. Content analysis was used to analyse the qualitative data from KIIs and FGDs to determine commonalities within the responses.

The analysis focused on determining the supply gaps in lime supply (i.e. demand-current supply) and model future demand, given factors such as population growth, increased knowledge, use of lime and enhanced marketing activities. Additionally, financial analysis for viable business units, including the investment and annual running costs, the projected revenues and net annual margins/ profits were undertaken. Financial measures, including return on investment (ROI), payback period (PBP) and break-even point (BEP), were calculated. At the farm level, a comparison of costs of production, yields, total revenues and gross margins was undertaken. An analysis based on the Net Present Values (NPV) and the Benefits-to-Cost Ratio (BCR) was undertaken.

3.5 Study limitations

Overall, the Global Coronavirus pandemic (Covid-19), affected the delivery timelines of this assignment. Other study limitations included the unavailability of key respondents, especially on the supply side. In such instances, telephone, online platforms and email interviews were used.

Additionally, while the study team guaranteed anonymity, most of the lime manufacturers, distributors, and stockists considered financial and market information sensitive and thus uncomfortable to provide due to the business's competitive nature. Manufacturers and distributors highly guarded their sales prices and volumes sold to avoid disclosing their figures to the competition based on confidentiality clauses in their employment contracts and non-disclosure of proprietary information gathered during their work with various employers for agreed periods.

On a positive note, some individuals had moved from one distributor to another who offered some information that proved useful in assessing the sources and pricing of imported granulated lime and target customers. Indeed, the lack of information in certain areas was mitigated by the consultant's market knowledge in the agribusiness sector, especially in the fertiliser and plant health areas.

Lastly, with the absence of lime granulation factories in Kenya, information on the cost of granulation equipment and infrastructure was not readily available from target respondents. However, there are useful insights from the linkages of contacts interviewed during the KII on lime granulation. These were equipment suppliers in Tanzania, Morocco, USA, South Africa and China.

This study further utilised secondary literature while other cost data for equipment and infrastructure was obtained from contractors and equipment manufacturers located outside the county[23].

4

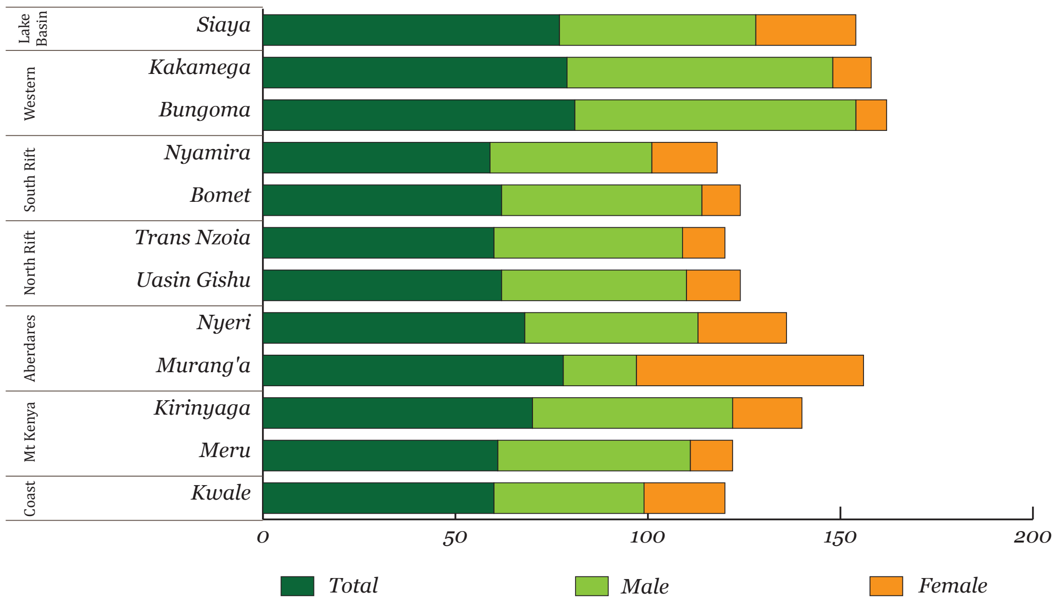
RESULTS AND FINDINGS

4.1 Household characterisation

4.1.1 Demographic characteristics of the sample

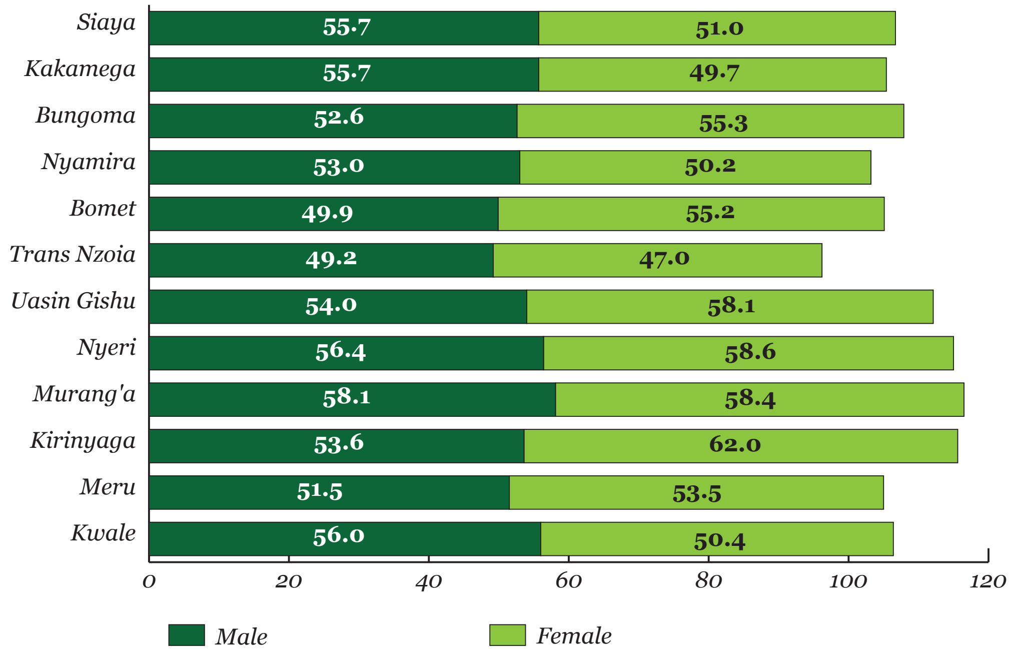
A total of 817 respondents were interviewed across the 12 counties and six regions. Most of the households interviewed were male-headed at 76.8%, while the female-headed households were 23.2% Female-headed households were highest in Coast and Nyanza at 35% and 33.8% respectively, while it was lowest in Western at 10.7%.

Figure 6: Distribution of respondents per county by gender



The average age of household heads was 53.52 years across the study areas; which is consistent with the known average age of Kenyan farmers at 60 years. The minimum overall age was 18 and the maximum age was 88 years. The aged farmer was the head of the household selected in his locality. He had useful insights on his experiences with production over his life time.

Figure 7: Average age distribution of respondents per County by Gender



The average household size was 5.5o persons. Households were larger in the Coast, Western and Lake Region at 7.1, 6.9 and 6.4 persons respectively while it was much lower in Mt. Kenya and Aberdare regions at 3.8 and 3.5 persons, respectively.

Table 1: Respondents household characteristics

Household	Size (No.)	Age (Years)	Sex of H/Hold Head	
			Male	Female
Average	***5.50***	***53.52***	***76.8%***	***23.2%***
Per Region:				
Coast	7.08	54.02	65.00%	35.00%
Mt. Kenya	3.81	53.94	77.86%	22.14%
Aberdare	3.53	57.62	71.03%	28.97%
North Rift	6.18	51.95	79.51%	20.49%
South Rift	6.00	51.65	77.36%	22.64%
Western	6.87	52.03	89.26%	10.74%
Lake Region	6.43	52.58	66.23%	33.77%

Source: Field Household Survey August, 2020

A majority (81.1%) of the respondents interviewed were married, 14.1% were widowed, 3.7% were single, while 1.1% of the respondents were either divorced or separated.

Table 2: Household respondents' marital status

Marital status	Single	Married	Divorced/ Separated	Widowed
Average %	*3.67*	*81.14*	*1.14*	*14.05*
Coast (%)	6.67	78.33	0.00	15.00
Mt. Kenya (%)	4.58	81.68	3.82	9.92
Aberdare (%)	5.52	81.38	1.38	11.72
North Rift (%)	4.92	85.25	0.82	9.02
South Rift (%)	3.77	75.47	0.94	19.81
Western (%)	0.67	89.93	0.00	9.40
Lake Region (%)	0.00	66.23	0.00	33.77

Source: Field Household Survey August, 2020

Level of education is an indicator of literacy levels and the ease with which target beneficiaries are likely to adopt proven technologies. From the study, 42.2% of the respondent had attained primary level education, while 38.5% had secondary school education. Those with tertiary and university level education were 9.2% and 3.4%, respectively. However, 6.5% of the respondents had no formal education. North Rift and South Rift regions registered high levels of higher education with 9.02% and 5.66% having attained University education with 13.11% and 18.87% attaining Tertiary education, respectively.

Table 3: Highest level of education attained

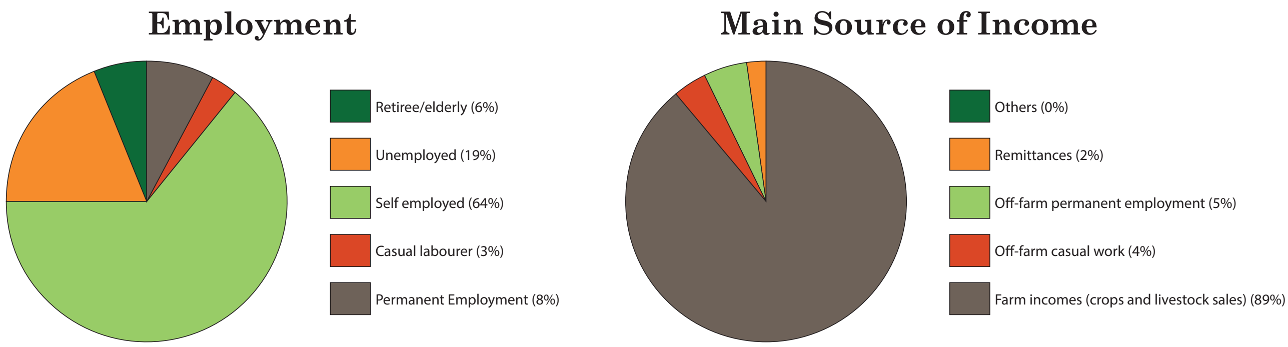
Education level	Combined Average (%)	Coast (%)	Mt. Kenya (%)	Aberdares (%)	North Rift (%)	South Rift (%)	Western (%)	Lake region (%)
None	6.46	8.33	4.58	6.21	9.02	8.49	1.34	11.69
Adult education	0.25	0.00	0.76	0.69	0.00	0.00	0.00	0.00
Primary education	42.15	36.67	45.80	46.21	35.25	33.02	40.94	58.44
Secondary education	38.48	50.00	38.17	38.62	33.61	33.96	48.99	23.38
Tertiary education (college)	9.24	3.33	7.63	6.21	13.11	18.87	8.05	5.19
University	3.42	1.67	3.05	2.07	9.02	5.66	0.67	1.30

Source: Field Household Survey August, 2020

4.1.2 Main occupation and sources of incomes

A majority (64.1%) of the respondents were self-employed, while 19.2% were unemployed[24], 8% were in permanent employment, 5.6% were retirees, and 3.2% were engaged in casual employment. More men than women were in permanent employment at 8.7% against 5.5% respectively. Those in self-employment were almost equally distributed with 64.7% for the men and 61.2% for the women. However, more women were unemployed (24%) against 17% for their male counterparts.

Figure 8: Household employment and main occupation



Source: Field Household Survey August, 2020

Unemployment was higher in the Western and Lake Regions at 31.5% and 41.6%, respectively while it was lowest in the Aberdare region at 1.4%. The main occupation of most of the respondents (84.4%) was farming. Eight per cent of the respondents were engaged in business, 5.6% were on salaried employment, while 1.4% engaged in casual labour as their source of livelihood. This implies that even those who reported to be unemployed relied on farming as their main occupation.

Table 4: Employment status based on gender

Type of Employment (%)	Male (%)	Female (%)
Permanent employment	8.73	5.46
Casual labourer	2.97	3.83
Self employed	64.91	61.20
Unemployed	17.79	24.04
Retiree/elderly	5.60	5.46

Source: Field Household Survey August, 2020

In comparison, and correlated to the major employment, farm incomes from crops and livestock enterprises were the main source of income for 89.5% of the respondents. Off-farm employment followed at a distant, with 5% of respondents who depend on off-farm permanent employment; and 4.2% who depended on off-farm casual labour. A further 1.5% of the respondents received remittances from other family members as their main income source.

4.1.3 Land holding and land utilisation

Coupled with enterprise mixes, land holding is an indicator of investments that one can or cannot make on their farm. For example, it is unlikely for squatters or those leasing land to make long-term investments on land. Lack of a title deed to a piece of land also limits credit access.

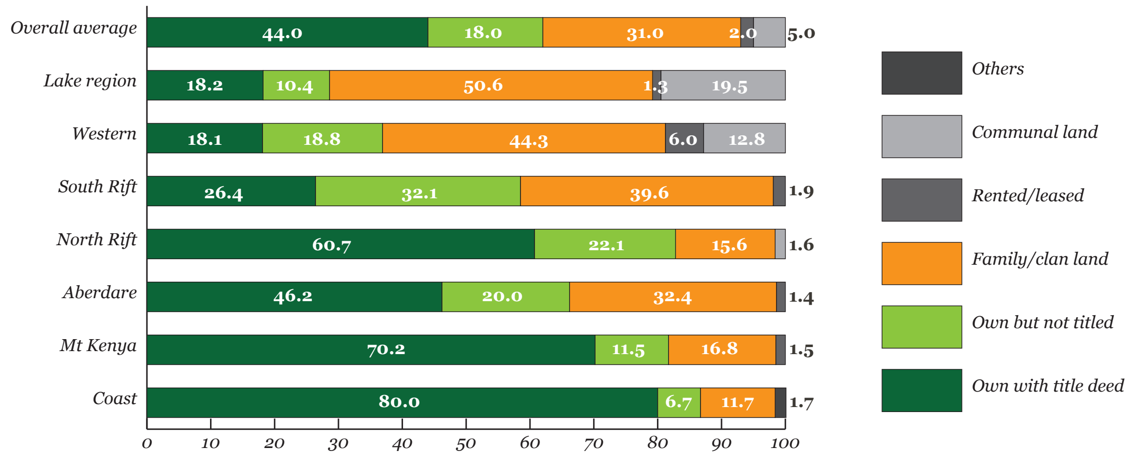
Different regions in the country are known to exhibit different land holding patterns. Coastal and the Rift Valley areas have more extensive land holding patterns as compared to Central and Western regions. North Rift, Coast, and South Rift regions had larger land holdings at 9.65, 8.42 and 4.34 acres, respectively. In comparison, the Lake Region, Aberdare's, Western and Mt. Kenya had the lowest at 1.54, 1.62, 1.79 and 2.53[25] acres, respectively.

Table 5: Total land holding per region

Region	N	Mean (Acres)	Land Holding in acres	
			Min	Max
North Rift	122	9.65	0.30	200.00
Coast	60	8.42	1.00	53.00
South Rift	106	4.34	0.40	40.00
Mt. Kenya	131	2.53	0.19	80.00
Western	149	1.79	0.20	15.00
Aberdares	145	1.62	0.13	5.00
Lake Basin	77	1.54	0.25	6.00

Overall, 44% of the respondents possess a title deed to the land they owned. However, 18% had no titles to the land they owned and occupied, and 31% were within land that was owned by their families and/or clans. Five per cent of the respondents were in communally-owned land while a further 2% used leased land for their agricultural activities. In Coast, 1.7% were noted to be squatters.

Figure 9: Land ownership by type and region



Source: Field Household Survey August, 2020

Regionally, Coast had more respondents with titles at 80% while in the lake region, most of the land was family/clan land at 50.7%. Titled land ownership was observed more in Coast, Mt. Kenya Aberdare and North Rift regions, while family-owned land was more prevalent in the Lake, Western and South-Rift regions. Land was leased more in western (at 6%) than in other regions.

Land was mainly used for crop production. The South Rift and Coast regions had the lowest total cropped area (as a percentage of total land holding) at 43.5% and 56.7%, respectively. Mt Kenya, Aberdare and Lake Regions had a large proportion of the land holding being put into crop production at 81%, 78% and 76% respectively. Western and North Rift recorded land utilisation rates of 72% and 65%, respectively for crop production.

Table 6: Total cropped area

Total Size of Land that is used for Crop Production			
	Av. Land Holding (Acres)	Av. Cropped Area (Acres)	Percentage of cropped land
Coast	8.42	4.77	56.67%
Mt. Kenya	2.53	2.04	80.95%
Aberdare	1.62	1.26	77.89%
North Rift	9.65	6.27	64.97%
South Rift	4.34	1.89	43.55%
Western	1.79	1.30	72.48%
Lake region	1.54	1.18	76.26%

Source: Field Household Survey August, 2020

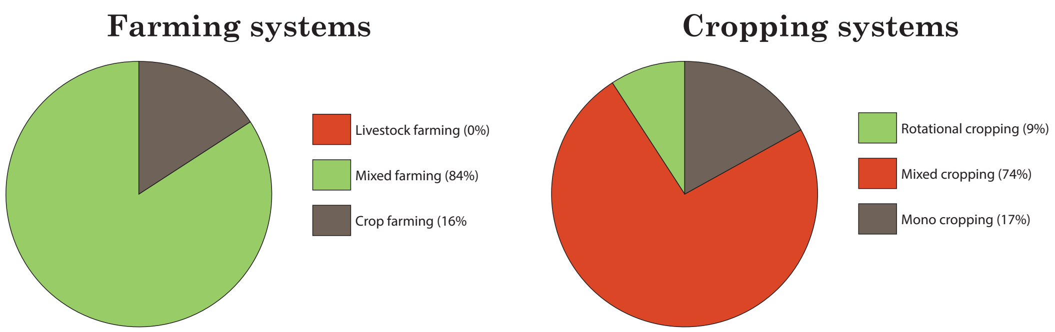
Land was mostly for crop farming, fodder production and establishment of the homestead. Livestock was kept within the areas set aside for the homestead. In Central Kenya (Mt Kenya and Aberdare regions), the bulk of farmers practiced zero grazing and established woodlots within their farms.

4.2 Agricultural production and services

4.2.1 Current farming systems

Most of the respondents (84%) practiced mixed farming, while 15.5% and 0.5% exclusively practiced crop farming and livestock farming respectively. In crop faming and mixed farming enterprises, farmers commonly grew a mixture of cereals (maize, sorghum, millet and wheat); pulses (beans, cowpeas, green grams, groundnuts, French beans, peas and soya beans); tubers and roots (potatoes, sweet potatoes, cassava and yams); and vegetables (African leafy vegetables, kales, cabbages, carrots, onions, and tomatoes). Nuts included macadamia, cashew nuts and coconuts. Industrial crops included sugarcane within the Lake Region, coffee and tea in Mt. Kenya, Aberdare, South Rift and Western regions. An assortment of fruit trees was also grown within the study area, including avocadoes, bananas, citrus, oranges, and mangoes among others. Fodder crops were also common especially in Mt. Kenya, Aberdare, Rift Valley and Western regions.

Figure 10: Current farming and cropping systems



Source: Field Household Survey August, 2020

4.2.2 Current cropping systems

Mixed-cropping was the most common cropping system practised by 74.2% of the respondents. Mono-cropping was the next preferred farming system at 17%. Mono crops included cash crops such as coffee and tea, commercial maize and sugarcane. Rotational cropping was practiced by only 8.7% of the respondents.

4.2.3 Major crop enterprises

Maize and beans were the most widely grown crops across all the regions with a total of 35.2% of the respondents growing maize while 14.5 percent grew beans. In parts of Western, North and South Rift, maize was commercially grown while in the other areas, maize was grown in small scale, (mostly as an intercrop with pulses), as it is a staple food for most household in the country. Fruits and vegetables were also widely grown across the 12 counties. Some of the notable fruits were avocadoes, oranges, passion fruit, bananas and mangoes.

Coffee was a major cash crop grown across four of the seven regions with an average of 12.5% respondents growing coffee. Its production was highest in the

Aberdare region (54.8%) followed by Mt. Kenya (17.5%), South Rift (3.3%) and Western (2.2%) regions. Tea was the second major cash crop grown mostly in Mt Kenya (18.1%) and South Rift (10.5%). A total of 5.4% had established tea farms, mostly in Mt. Kenya and South Rift.

Sugarcane was grown by 3.4% of the respondents and was mainly done in Western Kenya and parts of the North and South Rift. A total of 4.2% of the farmers grew potatoes with a bulk of this being in the Mt. Kenya Region (mainly Meru County). A comprehensive list of crops grown per region is attached as Annex 8.5 to this report.

4.2.4 Fertiliser use in agricultural production

Fertiliser is the most commonly used input in agricultural production and is comparable to agricultural lime in aspects such as manufacturing, distribution and application. Almost all farmers (97.7%), across all the regions used different types of fertilisers. Coast had the lowest reported fertiliser usage at 83.3% with all the other regions recording more than 90%.

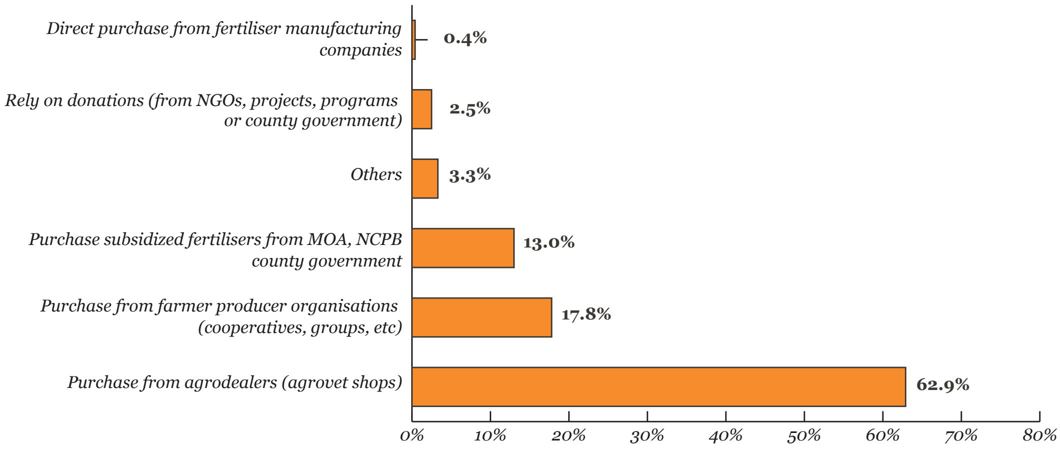
Table 7: Fertiliser usage

Do you use fertiliser for crop production (%)		
	No	**Yes**
Overall average	***2.3***	***97.7***
Coast	16.7	83.3
Mt. Kenya	1.5	98.5
Aberdare	2.1	97.9
North Rift	.8	99.2
South Rift	.8	99.2
Western	.6	99.4
Lake region	1.3	98.7

Fertiliser usage across the country is historical. Successive governments have promoted the use of inorganic fertiliser as a way of increasing productivity. Governments have also subsidised the cost of fertilisers and made them readily available and accessible by enhancing importation and distribution of fertilisers nationally. Some of the commonly used fertilisers included: Mavuno Planting Fertilizer; Di-ammonia Phosphate (DAP); Triple Supper Phosphate (TSP); Calcium Ammonium Nitrate (CAN); NPK Compound Fertilizer; Single Super Phosphate (SSP) and Urea.

For many farmers (62.9%), agro-dealers are the main source of fertilisers while farmer producer organisations such as cooperatives and farmer groups supply 17.8% of respondents. This shows the important role the two channels can play in supplying similar products such as lime. National and County Governments supplied 13.0% and another 2.5% relied on donations from NGO-led projects or programs and county governments.

Figure 11: Sources of fertiliser



On the contrary, some farmers reported not using fertiliser. Their reasons were; higher prices and hence unaffordable (36.4%), lack of supply/unavailability (9.1%), the perceived their land to be adequately fertile (9.1%); and 18.2% did not know how to use fertiliser. Other reasons sighted were use of organic farming, where the farmers were using bio-fertilisers and not synthetic ones.

4.2.5 Farm labour and types

Current forms of available agricultural lime are often labour intensive. Availability and cost of labour are therefore important considerations for adopting the use of lime for farm use. From the study, the family unit was the main source of farm labour followed by casual labour. A total of 71.3% of the respondent interviewed during the household survey relied on family as the main source of labour in their farms, 28% used casual laborers as their main source of labour, while only 0.8% relied on permanent employees.

Table 8: Main source of family labour

Main source of farm labour expressed as a percentage								
	Average (%)	Coast (%)	Mt. Kenya (%)	Aberdare (%)	North Rift (%)	South Rift (%)	Western (%)	Lake (%)
Family labour	71.3	86.7	68.7	72.4	44.3	65.1	83.2	89.6
Casual laborers	28.0	11.7	31.3	27.6	54.1	33.0	16.8	9.1
Permanent laborers	.8	1.7	0.0	0	1.6	1.9	0	1.3

North Rift had the highest composition of casual labour at 54.1%, while South Rift and Mt. Kenya had 33.0% and 31.3%, respectively. The high disparities in use of casual labour between North Rift, South Rift and Mt. Kenya as contrasted with Coast, Western and Lake Regions, can be attributed to the relatively high land holdings, the small household sizes, and the nature (and intensiveness) of their crop production enterprises. North and South Rift have a relatively larger land holding as compared to the other regions and therefore family labour is not sufficient to provide adequate farm labour. The sampled Mt. Kenya and Aberdare regions were predominantly coffee, tea and dairy production areas; these enterprises are comparatively labour intensive, thus hired farm hands gives the much-needed abridgment of labour resource. In comparison, the Coast, Western and Lake Regions have comparatively larger family sizes and engage in lesser intensive farm enterprises. On average 2.59% of adult family members and one per cent underage (below 18 years) family member were engaged in farm labour.

4.2.6 Gender roles in agricultural production

Gender participation has an impact in agricultural production and in the use of inputs such as lime. The survey showed that roles in the production process are shared across both male and females, although some activities still exhibit some predominance of one gender over the other. Land preparation was predominantly a male role while planting and crop husbandry is marginally done by women. Also, harvesting and post-harvest handling, records keeping and sale of surplus yields were marginally a female-dominated role. More men, however, attended training and seminars on crop production and were more involved while making decisions related to spending of proceeds from farming. This indicates that men ought to be a key driver in promoting the use of lime and granulated lime.

Table 9: Gender responsibilities in production activities

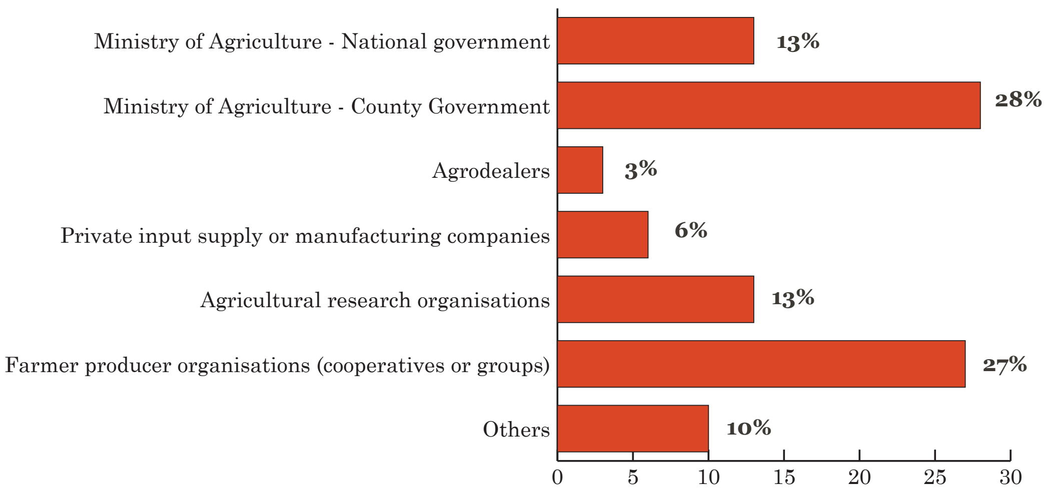
Mainly Responsible (as a Percentage)	Male	Female	Children	Both Gender
Land preparation	34.4	24.1	1.1	40.4
Planting	18.2	26.6	.9	54.3
Crop husbandry	19.4	22.9	2.7	55.1
Harvesting	14.6	24.2	1.3	60.0
Post-harvest handling	16.1	30.0	1.6	52.3
Record keeping	32.3	38.2	2.2	27.3
Selling of surplus	29.9	34.9	.9	34.3
Attending training and seminars	37.2	37.8	2.5	22.4
Spending on incomes earned from farming	34.4	28.4	1.0	36.2
Other tasks	21.6	31.9	9.0	37.5

4.2.7 Agricultural extension services

Agricultural extension, including training and information sharing, is an important precursor to changing the perceptions and behaviour of farmers' towards adopting new ideas and technologies including use of inputs like lime. From the household survey, only about 36.2% of the respondent had accessed extension services within the last one year. Of these, about 5.6% access the services on a weekly basis, 25.5% irregularly, 28.3% once a year, while 11.5% accessed services on a need basis. Coast Region and Mt. Kenya region had more farmers accessing agriculture extension at 55% and 45.8%, respectively. Lake Region and North Rift had some of the least levels access at 24.7% and 24.6%, respectively. The frequency and level of access could affect adoption and use of inputs and targeted lime products.

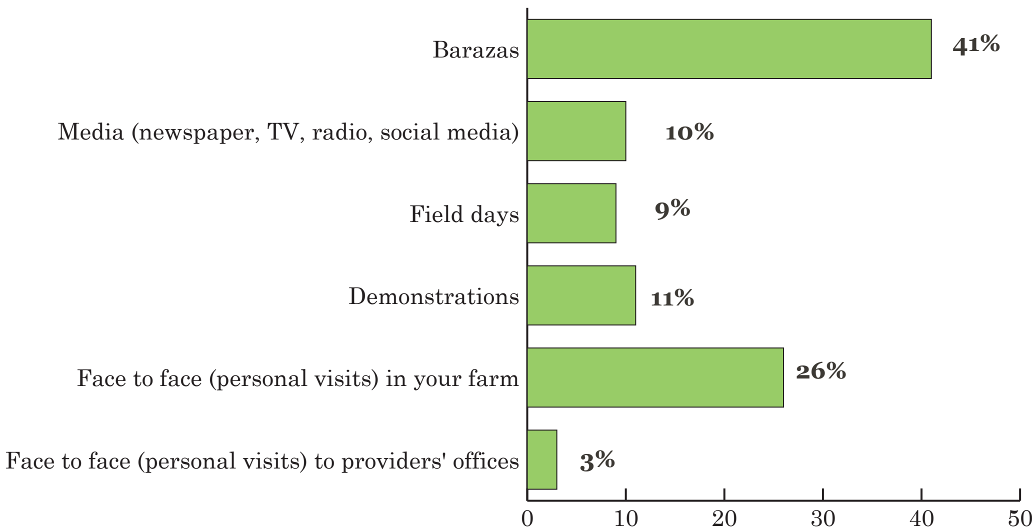
The two major sources of extension services were the County government through the line ministries of Agriculture and livestock and its relevant departments (28%) and farmer producer organization such as cooperative societies (27%). The National Government through the Ministry of Agriculture and national programs provided services to 13% of respondents, while a similar number (13%) received extension service from various agricultural research organizations such as KALRO and Coffee Research Foundation (CRF). 10% of the respondent did access extension services from NGOs that included: Agrics East Africa, One Acre Fund, Syngenta Foundation, Technoserve, Vi-Agroforestry and World Vision Organization. And 6% of the respondents access extension services from the private input suppliers, large scale farms and manufacturing companies. Others organizations that provided extension services to the farmers were the seed manufacturers such as East African Seed Company and Kenya Seed Company (KSC) Ltd. These organizations could be good avenues to introduce and promote use of granulated lime; hence their incorporation in such efforts is important.

Figure 12: Sources of extension service



The most common mode of extension services delivery included public Barazas (41%), face to face personal visits by providers to farms (26%), and demonstrations (11%). Other delivery modes included media (10%), field days (9%), and farmer visits to the service providers' office (3%). Despite government extension services being demand driven, visits to the extension staff offices was the least used mode of service delivery; meaning that demand driven approaches may not be working as intended.

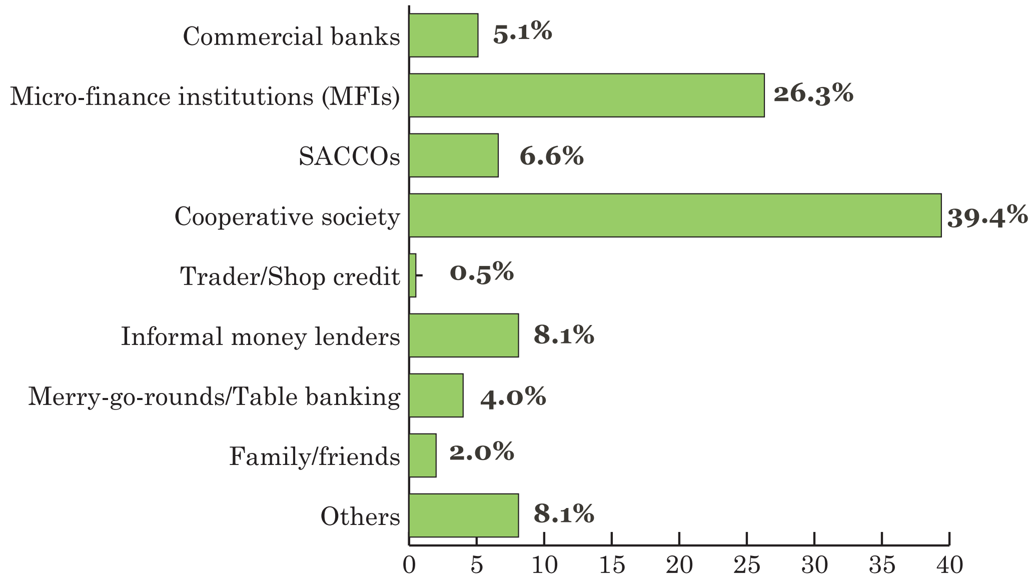
Figure 13: Mode of extension services acquisition



4.2.8 Access to credit

Wider use of lime and granulated lime could be accelerated through provision of credit on the same, especially given than majority (87.3%) of respondents indicated purchase farm in puts was the main financial need. Credit access is vital in agricultural production systems as it facilitates cash flows to purchase inputs, pay for labor and mechanized services, value add, and market agricultural produce and thus earn income. At the time of the feasibility study, only a small proportion of farmers accessed credit services for their agricultural activities. 22.7% of the respondent accessed credit in the past one year, the remaining 77.3% 0f the respondents had not accessed any form of credit. Access to credit services was high in Mt Kenya, Western and Nyanza region with 33.6%, 26.2% and 28.6% respectively. Access to credit was lowest in Coast and south rift at 15% and 16% respectively. More men accessed credit at 77.4% compared to the women at 22.6%.

Figure 14: Source of credit



Most of the farmers accessing credit had two major sources; cooperative societies and Micro-Finance Institutions (MFIs) at 39.4% and 26.3% respectively. This points to the important role that farmer organizations, including cooperatives, can play in providing financial and credit access to producers include on new technologies and products like granulated lime. A further 6.6% and 5.1% accessed credit from SACCOs and commercial banks respectively. Informal sources such money lenders/shylocks served 8.1%, Merry-go-rounds/table banking served 4.0% of the farmers, family/friends (2%) and from the agrovets/shops (0.5%).

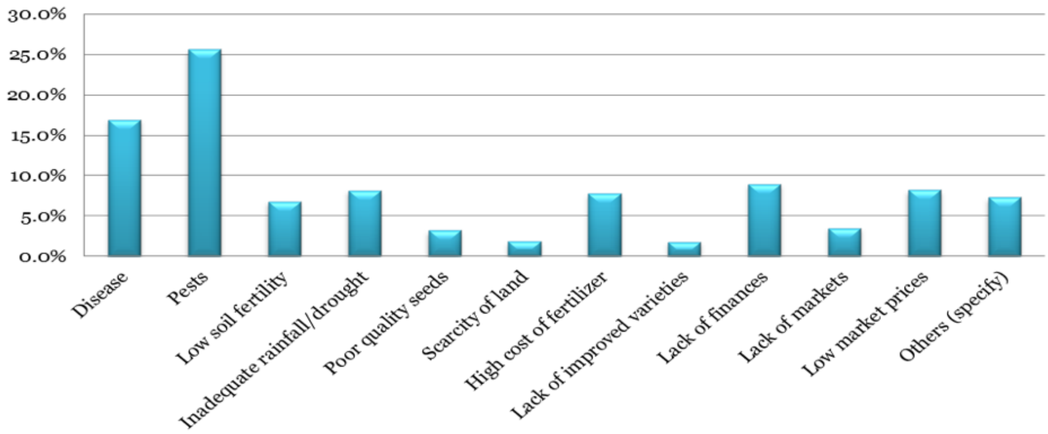
Purchase farm inputs such as seeds, fertilizer and other agrochemicals was the major financial need for a majority (87.3%) of those accessing credit. A total, 5.3% used the credit on activities unrelated to their agricultural production, despite borrowing for agricultural reasons. A further, 2.1% accessed credit to pay for the farm labour, 0.5% to acquire agricultural assets while 4.8% invested it in their businesses.

4.2.9 Crop production challenges

Some of the key challenges as regards crop production activities across the regions included; pest and diseases, at 25.6% and 15.9% respectively. Respondents also decried inadequate rainfall, high input cost (fertilizer) and lack of finances as some of their major concerns. Lack of markets (3.5%) was not so prominent as compared to the low market prices (8.2%); this was indicative of the availability of markets but poor market condition such as poor prices was a concern to the farmers. Low soil fertility was reported by 6.8% of the respondent, this was significant as it is indicative of an appreciable farmer population understanding that soil condition as a contributor to the observed pattern in their crop production cycle. Soil condition as contributor to crop performance is related to soil acidity, hence justifying the need for use of lime.

In Western and the lake regions, pest diseases and lack of finances were some of the biggest challenges. Inadequate rainfall was a significant challenge to the farmers in South Rift. In addition to diseases and pests, low market prices and lack of finances were some of the most significant challenges the farmers in Mt. Kenya and Aberdares regions.

Figure 15: Source of credit



Low soil fertility was a significant concern to the respondents in Coast (24.2%), Western (8.3%), North Rift (7.0%), South Rift (6.5%) and Lake Region (6.8%) but the farmers in Mt. Kenya and Aberdare regions did not express a serious concern on the quality of their soils as being significant challenge.

A reasonable majority of the farmers interviewed in the focus groups and within the households acknowledged reduced crop yields with most attributing it to climatic changes, pest and disease infestation, over cultivation, use of poor-quality inputs, soil erosion and continuous usage of acidic fertilizer; the later pointing to the need to use lime. However, there were a few respondents who did not know why soil health is important indicating that there are knowledge gaps about soil health and soil quality concerns, including the appropriate mitigation measure to address the soil quality.

There is also low level of awareness of soil acidity testing and effects of acidity on crop productivity. There is little knowledge on cost and where to access soil testing services. Promotion of increased uptake of lime need be accompanied with efforts to increase awareness on effect of soil acidity on production. Some County departments of Agriculture are involved in soil testing and it collaborates with partner like soil cares, KEPHIS and KALRO and the soil charges range from KES 1,000-2,000 per sample and depending with the physical and chemical tests required.

4.3 Current access and demand for agricultural lime

4.3.1 Knowledge of agricultural lime

Overall, 59.5% of respondents were aware of agricultural lime. The level of farmers' awareness was considerably high especially in Aberdares (95.7%), Mt. Kenya (67.9%), and North rift (62.3%). South rift, Western and Lake Regions registered awareness levels of 49.6%, 47.5% and 48.7% respectively. Awareness levels were lowest in the Coast region at only 13.3%. Higher awareness levels in the Aberdares and Mt. Kenya regions was mainly attributed to the role of coffee cooperatives in educating farmers about lime; especially given that 3 of the 4 sampled Counties are predominantly coffee growing Counties. The high level of awareness correlates well with the higher level of usage of lime in Mt Kenya and Aberdare regions; a further pointer for need of efforts towards increased awareness in the other regions to improve lime uptake.

Table 10: Awareness of agricultural lime

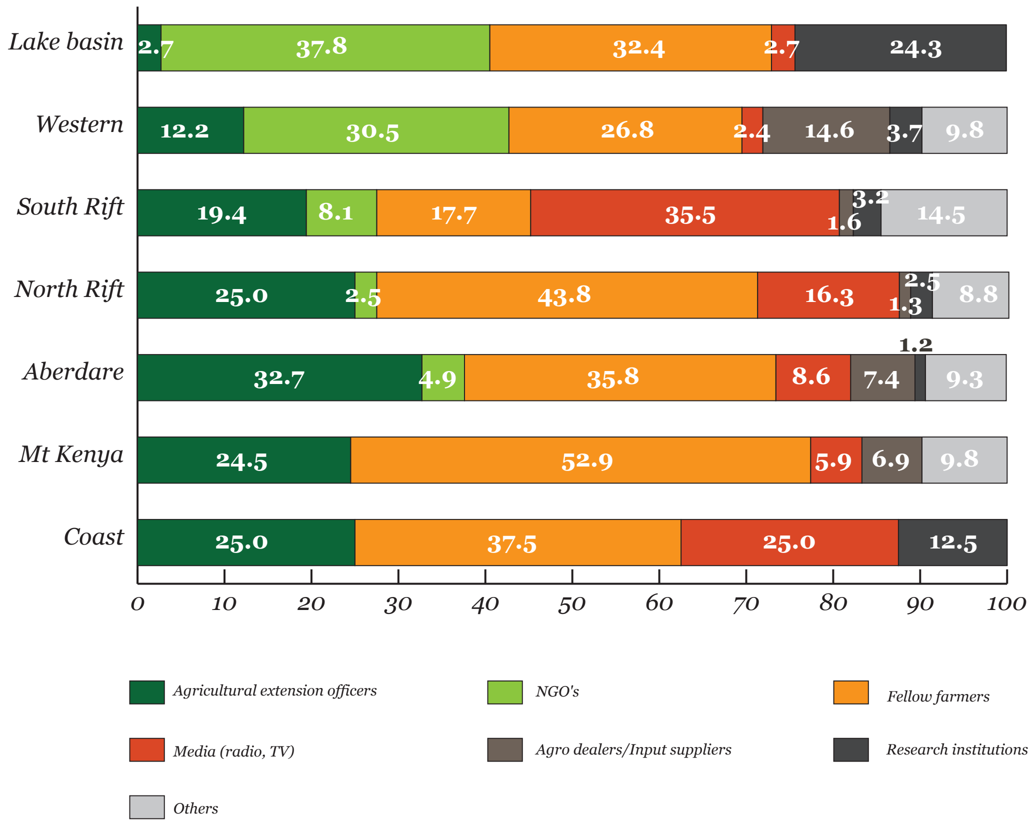
Region	Sample (N)	No		Yes	
		Frequency	%	Frequency	%
Overall averages	***817***	***331***	***40.5%***	***486***	***59.5%***
Aberdares	146	6	4.1%	140	95.9%
Mt. Kenya	131	42	32.1%	89	67.9%
North Rift	122	46	37.7%	76	62.3%
South Rift	121	61	50.4%	60	49.6%
Lake Basin	77	40	51.9%	37	48.1%
Western	160	84	52.5%	76	47.5%
Coast	60	52	86.7%	8	13.3%

4.3.2 Sources of information on agricultural lime

Farmers who reported being aware of lime, 52.9%, 43.8%, 37.5%, and 35.8% in the Mt. Kenya, North Rift, Coast and Aberdares stated the information sources as being fellow farmers. . Agricultural officers were a source of information to 32.7% in the Aberdares, 25% in Coast, 24.5% in Mt. Kenya, and 25.0% in South Rift.

In South rift Media played a big role in creating awareness on agricultural lime at 35.5% while farmers in Lake Region and Western accessed agricultural lime information mainly from Non-governmental agencies at 37.8% and 30.5% respectively. This was followed by fellow farmers at 32.4% and 26.8% respectively. Other reliable information sources that were used by the farmers included; agro-dealers/input suppliers as well as research institutions. In the lake region, research institutions such as KALRO was the third largest source of information on agricultural lime for farmers.

Figure 16: Sources of information on lime by region (%)



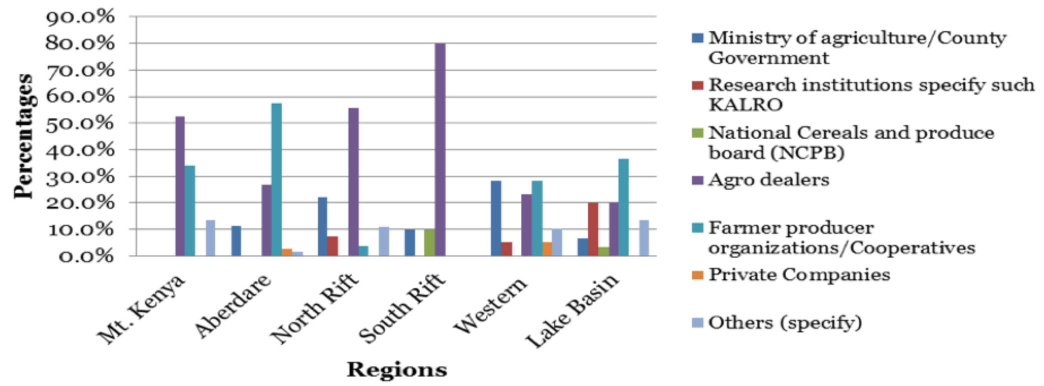
4.3.3 Access to lime

Despite the considerably high awareness on lime (59.5%), only 29.3% of the total respondent population had access to lime (meaning 70.7% did not). Of the 29.3% who reported to have access to agricultural lime were: Nyeri (6.1%), Muranga (5.1%), Kirinyaga (3.5%), Siaya (3.3%), Bungoma (2.4%), Uasin Gishu (2%), Kakamega (1.7%) Meru (1.5%), Trans Nzoia (1.2%), Nyamira (1.2%), and Bomet (1.1%), while Kwale did not report any lime usage.

4.3.4 Sources of lime

Sources of lime varied from one region to another. In Mt. Kenya, majority of the farmers accessing lime purchased it from agrovets/agro-dealers (52.3%) and Farmer Producer Organizations (FPOs)[26] (34.1%). In Aberdares, FPOs (57.4%) were the largest source of lime, followed by agro-dealers (27%) and Ministry of Agriculture (11.3%)[27]. In South Rift, agro-dealers provided 80% of the lime while Ministry of Agriculture and National Cereals and Produce Board (NCPB) provided the remaining 20%. In Western, cooperatives provided 28.2% of farmers, Ministry of Agriculture 28.2%, and agro-dealers-23.1%. In the Lake Region (Siaya), FPOs (36.7%), agro-dealers (20.0%) and research institutions (20.0%) were the some of the major lime sources. Agro-dealers were the major source of lime in North Rift, followed closely by the Ministry of Agriculture (22.2%).

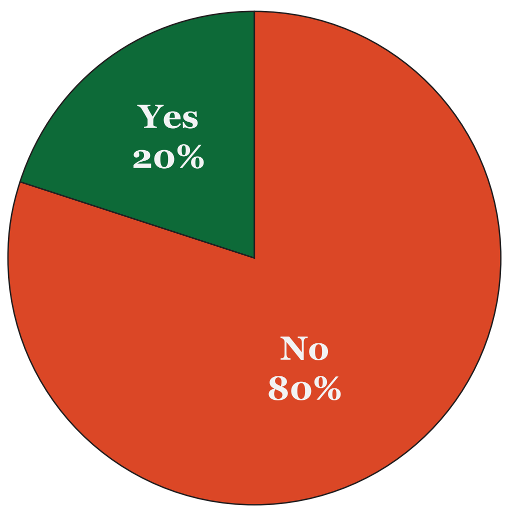
Figure 17: Sources of lime



4.3.5 Usage of agricultural lime

While considerable majorities (59.5%) of the study respondents were aware of agricultural lime, and whereas 29.3% had access to lime, only 20.2% of the respondents reported to have ever used lime in their farms. This means that a majority (79.8%) have never used lime. Out of those that reportedly used lime in their farms, 98.2% used powdered form of lime (ground lime)[28], and 1.8% used granulated lime[29]. This was mainly associated with the fact that powdered lime is the main available lime product in the Kenyan market.

Figure 18: Farmers with history of lime usage



Box 1

From Key informant interviews, the study revealed that there have been efforts to promote lime use by organizations such as AGRA, KALRO, KMT and County governments.

KMT, for example, have been involved in a lime project in North Rift and Western Kenya covering four counties (Bungoma, Kakamega, TransNzoia and Uasin Gishu).

In the Aberdares region, the County Government of Nyeri has supported coffee farmers with subsidized lime while coffee cooperatives, through their umbrella unions, have been widely involved in lime application drives in coffee farms.

Apart from Muranga, Kirinyaga and Nyeri Counties, other counties involved in such drives include Embu, Tharaka Nithi, Meru and Kiambu.

4.3.6 Current practices in lime application

While 2o.2% of sampled farmers are currently using lime, information on when and how to apply it is still unclear. This is mainly caused by mixed messages to farmers by various organizations that promote lime use.

Of the 20.2% that used lime, 8.9% applied lime before ploughing, 3.1% applied during ploughing and 3.5% before planting. An additional 2.7% applied lime during planting time and 1.9% way after planting.

Box 2

Ground lime is often applied by broadcasting/spreading and in most cases by hand. Some large scale farmers however, use mechanized lime spreaders. Organizations such as Homa Lime Company promote broadcasting lime all over the plant land before planting. One Acre fund has been promoting the use of lime in combination with high yielding seed varieties and use of farm DAP and CAN fertilizers. The organization promotes the use of lime during planting and in micro-doses, only applied on the planting holes and not spread all over the land. Majority of farmers who use lime apply it together with basal fertilizer during planting. KALRO recommends that lime application should be done after ploughing, before harrowing and when the soils are slightly moist between 3-6 weeks before planting ensuring that the lime is homogeneously distributed in the topsoil (0–30 cm).

Table 11: Timing of lime application

When do you apply lime?								
Region	Overall %	Coast %	Mt. Kenya %	Aberdare %	North Rift %	South Rift %	Western %	Lake region %
No. of liming Farms	165	1.0	18.0	98.0	9.0	3.0	16.0	20.0
Before ploughing	8.9		3.8	42.5	2.5			3.9
During ploughing	3.1		3.8	12.3	.8			1.3
Before planting	3.5		1.5	4.8	2.5	.8	5.6	9.1
During planting	2.7		.8	.7	1.6	1.7	4.4	11.7
After planting	1.8	1.7	3.8	6.2				
During plant growth	.1			.7				
Total	**20.2**	**1.7**	**13.7**	**67.1**	**7.4**	**2.5**	**10.0**	**26.0**

In addition to timing of application, a majority of respondents applied lime separately (17.4%) while a smaller proportion applied lime in combination with other inputs (2.8%), including fertilizers and seeds.

Table 12: How lime is applied

How do you apply lime to your farm?								
	Overall %	Coast %	Mt. Kenya %	Aberdare %	North Rift %	South Rift %	Western %	Lake region %
No. Liming Farmers	165	1.0	18.0	98.0	9.0	3.0	16.0	20.0
In combination with fertilizer	2.82		3.05	3.42	1.64	1.65	3.13	6.49
Applied alone/ separately	17.38	1.67	10.69	63.70	5.74	0.83	6.88	19.48
Total	**20.20**	**1.70**	**13.74**	**67.12**	**7.38**	**2.48**	**10.00**	**25.97**

Some studies have recommended that lime can be applied periodically ranging from every 2 years to 3 years (KALRO, 2016)[30] but if recommended quantities are applied. Application of lime at 6MT/ha will require another application 3 years later, application of lime at 4MT/ha will require another application 2.5 years later, while application of lime at 2MT/ha will require application every two years (KALRO, 2018)[31]. In the micro-dosing approach lime is applied every planting season. With regards to how often the 20.2% of farmers applied lime, a majority (9.3%) applied irregularly when they were able to or when needed[32], 7.7% applied once a year, 2.2% in every planting season.

Table 13: Seasonality of lime application

How often do you apply lime?								
	Overall %	Coast %	Mt. Kenya %	Aberdare %	North Rift %	South Rift %	Western %	Lake region %
No. Liming Farmers	165	1.0	18.0	98.0	9.0	3.0	16.0	20.0
Every season	2.20	0.00	0.76	9.59	0.00	0.83	0.63	1.30
Once a year	7.71	0.00	8.40	24.66	1.64	0.83	6.25	3.90
Twice a year	0.98	0.00	0.00	5.48	0.00	0.00	0.00	0.00
When able to /when need arises	9.30	1.67	4.58	27.40	5.74	0.83	3.13	20.78
Total	**20.20**	**1.70**	**13.74**	**67.12**	**7.38**	**2.48**	**10.00**	**25.97**

4.3.7 Quantities of lime used

When combined with the percentage of farmers using lime, the current quantities used per farmer are used to estimate the existing demand. Given that there have been different and varying methods of lime application, the quantities applied per unit area ranged widely amongst farmers using lime as there was no standardized application methodology or quantities. This ranged from 50kgs to 1,500 kgs (average of 118Kgs per acre or (approximately 2.25 -50kg bags).

Lime use in coffee averaged 336.9 kgs per acre (832 kgs/ha) ranging from a low of 50kgs to a maximum of 2 MT/acre. Notably, the quantities currently used are still lower than the recommended amounts even under micro-dosing practices. Lime use in maize was lower than that of coffee and averaged 105.9kgs per acre (262 kgs/ha). This may be attributed to the practice of micro-dosing which was common in maize as opposed to broadcasting which was common in coffee.

Box 3

There lacked a standardized recommendation on the amount of lime to be applied per unit area of land. Previous studies by KALRO have recommended up to 4 tonnes per hectare (or 1.6 tonnes per acre) but yields can also be optimized at 2 MT/ha (about 5 MT per ha) while used in combination of other inputs such as farmyard manures. The One Acre fund uses micro-doses averaging 0.5 MT/ha. A field study conducted in Zambia (Mulungu et al, 2013) indicated that lime applied at such reduced rates as between 100 to 200 kgs of lime can be profitable in maize, soybean and groundnut production. When combined with compost, marginal returns can be as high as 150 per cent.

Table 14: Lime use in different crops

Crop	Observations (n)	Average area cropped (Acres)	Mean	Minimum (kgs/acre)	Maximum (kgs/acre)	Qty applied/ acre
Maize	54	0.88	93.13	(Kgs)	850	105.9
Coffee	91	0.65	218.96	50	2,000	336.9

"I applied lime in my farm where I grow Rhodes Grass; I was able to realize increased yields from 90 bales to 170 bales and I realized increased tomato yields from 70 to 90 crates"

–Farmer from North Rift

4.3.8 Price structure of agricultural lime

On average, powder lime costs Kshs. 6,000 per MT, for ex-factory prices. Purchase price from manufacturer/importer per 50kg bag average Kshs. 250 (or Kshs. 5 per kg), loading fee is Kshs. 3 per 50kg bag, and transport is Kshs. 15 for a 50 kg bag and offloading is Kshs.3 per 50kg bag. Eventually agro-dealers retails a 50kgs bag at Kshs. 350 per (or Kshs.7 per kg). Notably transportation costs makes up to 5% of the sales price and 19% of the gross margins.

From FGDs with coffee cooperatives in Mt. Kenya and Aberdares regions, lime prices ranged between Kshs 350 and Kshs 500 for a 50Kg bag from the cooperative and between Kshs.600 to Kshs. 750 from agro-dealers. Additionally, prices of lime rarely varied from one season to another. Farmers however, noted that they would consider up to an average of Kshs. 10 per kg of lime to be a fair price. In addition and out of the farmers who used lime, 55.1% noted that it was affordable, indicating that lime price was not a major challenge to producers.

4.3.9 Crop yield changes with lime application

Previous studies have estimated that yields in maize can increase by between 10 to 20% with lime use. Changes in the crop yield as a result of liming were also a contentious issue to the farmers. During the FGDs changes in crop yields registered mixed reactions, some of the farmers who had used lime in Kakamega, reported marginal increases in their crop yields while some reported no changes in their maize yields. One Acre Fund has been in the forefront in promoting lime usage in some of the sampled Counties among them Bomet, Uasin Gishu, Trans Nzoia, and Nyeri Counties. It was also established during the FGD, there was some increases in maize crop yields in areas such as Bomet, Uasin Gishu and Trans Nzoia; with about 15% to 20% increases in yields.

Lime was mainly applied on maize across Rift Valley and Western, coffee in Mt. Kenya and Aberdares regions and in some instances sugarcane fields in Western Kenya. Analysis shows a positive difference in yields when lime is applied as compared to when lime is not applied. Results show that for maize yield increased by up to 83% while for coffee yield increased by up to 62.9% per acre.

Table 15: Yield differences with and without lime

Crop	Average are planted (acres)	Average lime applied (kgs)	Equivalent lime applied per acre	Average yields (Kgs)/acre without lime	Average yields (Kgs)/acre with lime	Difference in yields per acre (kgs), with & without lime
Maize	0.88	93.2	105.9	448.5	822.2	83.3%
Coffee	0.65	219.0	336.9	2,051.7	3,342.3	62.9%

It was difficult to establish the contribution of liming on the achieved crop yields given that most of the farmers who applied lime in their farms combined it with use of inorganic fertilizer and organic manure. Farmers therefore register varied results in so far as their crop yields are concerned.

From KIIs with stockists, it was noted that many small-holder farmers do not maintain data on their lime use or even when and where they applied; they are thus unable to quantify the change in yield as a result of the lime applied. Many farmers claim they see change but not measurable. It is necessary to provide training on lime application techniques – when to apply and quantity. Among large scale farmers, they keep proper records and can establish relationship between change in crop yield and lime application and report of increase in 30-40% in yield. Controlled experiments done by KALRO and One Acre Fund shows the effect of lime to be an increase in maize yields by between 12 and 20%.

4.3.10 Challenges in access and use of lime

Lime, as currently available in powdered form, has been known to be bulky, dusty, and difficult to apply, and many cases unavailable to farming households. In addition, the key challenges include the following:

- Large quantities are required for application per unit area, especially compared to other inputs such as fertilizers,
- Few agro-dealers stock lime as it is bulky and it has low demand. Of the 20.2% of farmers using lime, 12.6% noted that lime was difficult to find.
- Lime is expensive to transport because of its bulkiness,
- Powdered lime form is difficult to apply as it is dusty and easily blown away by wind, and
- Lime application is labour intensive.

4.4 Demand for Granulated lime

4.4.1 Knowledge and preference of granulated lime

There is low awareness of granulated lime in the study areas at only 1.1% of the respondents. However, all the respondents that participated in the study have never used granulated lime before but 67.9% would be willing to use granulated lime in the future.

The study also established that the respondents (59.4%) would prefer the granulated form of lime, 33.9% would still prefer to stay with the powdered lime while 6.1% would prefer liquid lime. There were various reasons fronted for the preference, but the most prominent ones were that powdered lime was bulky, dusty and potentially hazardous during the application, and that any other form of lime that would address these concerns would be a relief to farmers. Notably, those who would still prefer the powdered lime did so because it is the only lime form they have experience using.

4.4.2 Willingness to pay for granulated lime

The advantage of granulated lime is that it has higher level of accuracy and one does not need protective clothing during application as is the case with powdered lime. It is also easier to apply and can be micro-dossed. However, there is the perception that granulated lime could be relatively more expensive than powder lime. Farmers are willing to pay up to Kshs. 30 per kg for the granulated lime; insisting that it should be lower than the cost of fertilizer.

"The biggest problem with powdered lime is not price; it's in fact quite cheap. The challenge is its dustiness and difficulty in application. If granulated lime was available and if it can be applied sin a similar manner as fertilizers I can pay as much as KES 1500 per 5okgs bag (or KES 30 per kg)"

Coffee famer from Mukurweini, Nyeri

4.4.3 Projected future demand and demand centers for granulated lime

Three demand centers for lime were identified including the following:

- **Central region**- including Mt. Kenya and Aberdares. The major crop where lime is applied is coffee which is grown in the Counties of Nyeri, Murang'a, Kirinyaga, Kiambu, Embu, Tharaka-Nithi and Meru.
- **Rift Valley region**- including both North and South Rift Counties of Uasin-Gishu, TransNzoia, Nakuru and Bomet. The major crop where lime is applied is maize. This is mainly applied once a year, before the start of the planting season.
- **Western and Lake Region**- The two main crops in these areas includes maize and sugarcane. This is a large area comprising the Nyando sugar belt and maize producing areas. Key demand Counties includes Kakamega, Bungoma, Kisumu, Siaya, Busia, Vihiga, and Homabay.

Projection of future demands is based on the following assumptions:

- At least 67% of all other farmers (who expressed willingness to use lime) will actually adopt the use of lime in the long run
- The quantities of lime used for the different crops currently will increase by at least 50% in the short run (5 years) and by 100% in the long run (10 years)
- The population of farm families involved in the three key crops that demand lime will remain constant within the first 5 years (short run) after which it will increase by 5% every 5 years
- The average area per household that is under each of the tree major crops will remain constant (assumes that farmers have already optimized land use)
- Current lime use per ha is coffee-832 kgs; Maize -262 kgs; and Sugarcane - 150kgs[33])

The resultant demands per region and the total for the three major regions is estimated at approximately 187,000 MT annually as shown in Table 3-17 below. This is projected to increase to 319,000 MT in the next 5 years and then to 532,000 MT in ten years' time.

Table 16: Estimated current and future demand for agricultural lime

Region	Major crop	Total are under crop	Current Lime use per Ha (Kgs)	Average area/farmer	No. of farmers	% of farmers using lime	Total lime demand (MT)
Central	coffee	150,000	832	0.263	570,000	67.0%	83,616
Rift valley	Maize	240,000	262	0.356	673,636	67.0%	42,130
Western & lake	Maize	130,000	262	0.356	364,886	67.0%	22,820
Western & lake	Sugarcane	70,000	150	0.6	116,667	67.0%	7,035
Rest of the country							31,120
Total- Current (MT)							**186,721**
Short run -5 years							
Central	coffee	150,000	1,248	0.263	598,500	67.0%	131,695
Rift valley	Maize	240,000	393	0.356	707,318	67.0%	66,354
Western & lake	Maize	130,000	393	0.356	383,131	67.0%	35,942
Western & lake	Sugarcane	70,000	225	0.6	122,500	67.0%	11,080
Rest of the country							73,521
Total- short run (MT)							**318,593**
Long run- 10 years							
Central	coffee	150,000	1,664	0.263	627,000	80.0%	219,648
Rift valley	Maize	240,000	524	0.356	741,000	80.0%	110,669
Western & lake	Maize	130,000	524	0.356	401,375	80.0%	59,946
Western & lake	Sugarcane	70,000	300	0.6	128,333	80.0%	18,480
Rest of the country							122,623
Total- long run (MT)							**531,365**

4.5 Supply of agricultural lime

4.5.1 Lime manufacturing

Agricultural lime is currently available in the Country but mostly the powdered lime. There are at least 13 companies that are involved in manufacture and distribution of lime and lime products (see Annex 7.4- Available lime products). Two main companies namely Athi River Mining and Homa Lime have the highest market shares for lime. The current demand is estimated at 150,000 MT annually. Low demand from farmers is currently the biggest challenge to lime manufactures. This is associated to low awareness among farmers. There is therefore need for awareness creation on liming benefits and uses so as to trigger increase in demand.

4.5.2 Lime distribution

The key channels for distribution of lime included manufacturers appointed stockists and distributors and retail agro-dealers. Others included NGOs projects and programs, coffee cooperative societies and County government's subsidy programs.

- Factory appointed distributors/stockists: Larger companies such as ARM and Homa Lime Company distribute lime through appointed agents located in different tows. In Homa Lime for example, stockists purchase lime at Kshs. 250 for a 50kg bag and sell to smaller agro-dealers or farmers at Kshs.350 per 50kg bag.
- Retail agrovet shop: Retail agrovets are dotted in the majority of agricultural based Counties across the country. Unfortunately, only a handful of such agrovets stocked lime owing to low demands and bulkiness (meaning that agrovets needed storage space). Some agrovets avoided stocking lime because of its dustiness. Like many other agricultural inputs, demand for lime is seasonal where purchases are done within a month to the start of planting season.
- Large scale producers: A number of large scale producers of coffee, maize, and sugar cane purchase large quantities of lime directly from lime manufacturers. Although the quantities purchased vary, it is often in hundreds of tonnes.
- NGOs projects and programs: NGOs such as KMT, One Acre Fund, and AGRA and in collaboration with manufacturers, researchers and agro-dealers have been supporting the distribution of lime amongst other inputs. One Acre Fund supports farmers with a market bundle of agricultural inputs provided on credit. These include soil testing, fertilizer, seed and lime. Farmers choose appropriate inputs from the bundle of products and pay a down payment to ensure their products are delivered with the balance of the loan paid at the end of the season.
- Cooperatives and Farmer Producer Organizations (FPOs). This is common with coffee cooperatives in central Kenya. Coffee growing Counties of Kirinyaga, Muranga, and Nyeri, coffee producer and marketing cooperatives were actively supplying lime to their members. Most of these

sell lime at lower prices ranging from Kshs. 350 to Kshs. 500 per 50kg bag. However, these mainly reach the coffee farmers only leaving out farmers engaging in other crops. This model is also common in Embu, Tharaka Nithi, Meru and Kiambu Counties

- County governments in lime supply and support: Through the cooperatives, County government extension staff have been sensitizing farmers on the necessity of soil testing, conducting demonstration on various crops using lime e.g. bananas, maize and coffee as well as linking coffee factories and other farm input suppliers to services and inputs providers; this resulting in increased awareness of agricultural lime. In Nyeri County, coffee farmers were supplied with subsidized lime by the County through their cooperatives. In Muranga County, the County government though the cooperatives, selects farms where demonstrations are conducted but individual farmers buy lime on their own.

4.6 Supply and opportunities in granulated lime

Currently, granulated lime is available in the country but not at the required scale. Only a few manufacturers deal with granulated lime. Most of the granulated lime is imported from countries such as Germany and Sweden. Neelkanth imports from their sister company in Tanzania, while Elgon imports from Germany and Sweden. Manufacturing companies such as Omya and MEA are currently granulating lime locally.

The current consumption for granulated lime is also very low estimated at only 4,000MT annually. Granulated lime is more preferred because of its ease of application and it has a more long term effect on the soil compared to ground (powdered) lime. Also, granulation improves the ability to blend lime with other inputs as granules can even be mixed with fertilizer granules and then applied at once; hence cutting labour costs for lime application. Further, granulated lime is slowly released into the soil and continues acting for a longer period. There has however, been criticism with regard to its application through micro-dosing as not all soils in the farm are covered.

Opportunities exist for granulating lime given the current low supply and its application appropriateness compared to powdered lime. Also, opportunities for blending lime with fertilizers would improve its adoptability. However, research and trials for the blend response by crops will need to be supported by researchers and donor organizations, since it may be expensive and lengthy. With good market linkages for their farm produce, farmers will be catalyzed to use lime to increase yield per hectare, even though granulated lime may be more costly than powdered lime. To increase uptake price subsidization may be considered. This can come through subsidy and assistance to agrovets to stock granulated lime which is expensive.

5

ECONOMIC EVALUATION AND BUSINESS MODEL

5.1 Farm level economics of lime use

This study found out that lime is applied on maize across all the study regions. In Mt. Kenya and Aberdares regions, lime was applied mainly in coffee. Lime was typically applied in two main methods i.e. micro-dosing (promoted by One-Acre Fund) and lime spreading/broadcasting. The average quantities currently used were 118kgs per acre but differ widely based on the application method. In micro-dosing the average usage was 0.5MT/ha (200kgs/acre) while in broadcasting, farmers used between 2 to 4 bags (100-200kgs per acre. The recommended dosage while broadcasting was 4 tonnes per ha (1.6 tonnes per acre).

5.1.1 Evaluation scenarios

Different crops and application methods for lime imply differences in farm level economics for lime use. This evaluation analyses the Net Present Values and the Benefit to costs Ratios (BCR), based on the following scenarios:

Scenario 1: This scenario makes the following assumptions, based on the study findings:

- A farmer is producing maize on an average 0.88acre of land but does not use lime
- Farmer uses 2 bags (100kgs) of DAP fertilizers during planting and 1 Bag of CAN for topdressing per acre
- All the other activities and costs are consistent for all farmers and therefore do not influence the total variable costs

Scenario 2: This scenario makes the following assumptions, based on the study findings:

- A farmer is producing maize on the average 0.88acres of land
- Farmer applies lime by broadcasting, averaging 105.9Kgs/acre (262 kgs/ha)
- Lime costs Kshs. 400 per -50 kg bag (Kshs. 8 per kg)
- Farmer incurs additional costs for broadcasting lime estimated at 3 man days per acre at Kshs. 300 per man day, totalling Kshs 900 per acre or Kshs. 2250 per ha.

Scenario 3: This scenario makes the following assumptions, based on the study findings:

- A farmer producing maize and micro-dosing lime and using inorganic fertilizers;
- Lime costs Kshs. 400 per -50 kg bag (Kshs. 8 per kg), and
- Farmer incurs only a small additional labor cost for lime application as this is done during planting. The additional cost is estimated at 1-man day at Kshs 300 per man day (Kshs.750/ha).

Scenario 4: This scenario makes the following assumptions, based on the study findings:

- A farmer is producing coffee, uses inorganic fertilizers BUT does not use lime
- Farmer uses 2 bags (100kgs) of NPK fertilizers for top dressing, 2 times in a year; thus 4 bags per acre (500 kgs/ha)
- All the other activities and costs are consistent for all farmers and therefore do not influence the total variable costs

Scenario 5: This scenario makes the following assumptions, based on the study findings:

- A farmer producing coffee by broadcasting lime and also using fertilizers
- Farmer applies lime by broadcasting, averaging 336.9Kgs/acre
- Lime costs Kshs. 400 per -50 kg bag (Kshs. 8 per kg)
- Farmer incurs additional costs for broadcasting lime estimated at 3 man days per acre at Kshs. 300 per man day (Kshs 900 per acre)
- Farmer uses 2 bags (100kgs) of NPK fertilizers for top dressing, 2 times in a year; thus 200kgs per acre (500kgs/ha)
- All the other activities and costs are consistent for all farmers and therefore do not influence the total variable costs

Scenario 6: Granulated lime: This scenario makes the following assumptions, based on the study findings:

- A farmer producing maize as the main crop
- Farmer micro-dosing at least 500kgs of granulated lime per acre
- The price of granulated lime is Kshs.15 per kg,
- NO additional lime application costs as it is applied with fertilizers at planting time
- Farmer continues to use 2 bags of planting fertilizers and 1 bag of topdressing fertilizers
- All the other activities and costs are consistent for all farmers and therefore do not influence the total variable costs

5.1.2 Summary economic results and interpretations

The evaluation estimated farm level economics in terms of the net present value of accrued benefits (net befits) after incurring additional cost for lime purchase and application. Additional costs are estimated at Kshs. 2,300 and Kshs. 25,500 depending on the quantity of lime purchased. A maximum of 4 tons per hectare per year have been considered as the upper lime use limit.

Additional costs are incurred both in purchasing lime and labour costs for lime application. Broadcasting lime attracts at least 3 times higher costs as compared to micro-dosing; which is done together with planting and fertilizer application.

Results for different scenarios are as shown in Table 4-1 below and Annex 8.6. Differences are notable in the NPV and BCR levels for farmers using lime and those that are not. Returns are generally high mainly because additional costs for purchasing lime are low and because farmers may still not be applying recommended amounts.

Table 17: Summary of farm level economic indicators by scenario

Scenario	Crop	Lime use	Short run		Long run	
			NPV (KES)	BCR (ratio)	NPV (KES)	BCR (ratio)
Scenario 1	Maize	Nil	41,543.97	1.85	52,094.86	1.79
Scenario 2	Maize	Broadcasting	126,725.01	3.23	178,196.77	3.04
Scenario 3	Maize	Micro-dosing	128,438.16	3.36	193,863.40	4.15
Scenario 4	Coffee	Nil	465,682.47	5.83	610,582.8	5.83
Scenario 5	Coffee	Broadcasting	728,074.96	6.20	976,434.64	5.93
Scenario 6	Maize	Granulated lime	72,620.70	1.64	124,840.81	2.01

In maize, economic returns were higher in scenario 3 where lime is applied by micro-dosing. This is attributed to low amounts of lime used and thus low costs for purchasing lime. In addition, lime application while micro-dosing is applied together with planting, meaning that additional costs for lime application are inapplicable or minimal. In coffee, the BCR were higher for farmers using lime as compared to those that were not using lime; despite the additional costs for purchasing and applying lime. Even in the short run, coffee farmers who apply lime would get revenues that are 6 times more than the costs incurred.

For granulate lime, higher costs may lower the NPV but will still be positive. In the short run, potential benefits will be at least 1.64 times higher than the costs incurred increasing to 2.01 times in the long run.

5.2 Proposed lime processing and manufacturing

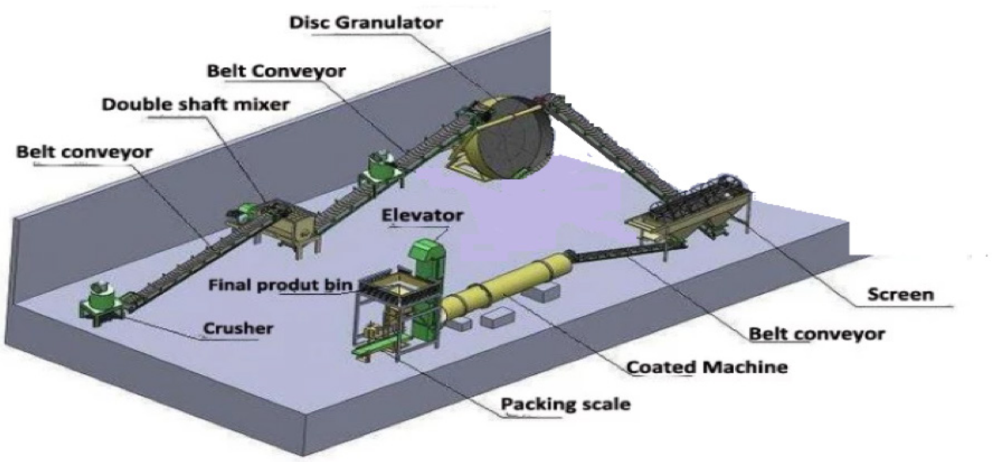
5.2.1 Plant design and capacities

Given the current total estimated lime demand of 150,000 MT p.a. three investment scenarios have been foreseen. These scenarios, includes investments in granulation while varying the plant capacities based on available modular granulation plants from manufacturers[34].The study considers three options for investments

1. Basic Investment. This is the basic systems that include belt conveyors, disc granulator and basic packaging machine.
2. Medium investments. The systems include mixer, belt conveyors, disc granulator, screen and basic packaging machine; and
3. High level investment system- The systems include mixer, belt conveyors, disc granulator, screen, dryer, cooler, dust collector and elaborate packaging machine (Figure 4-2)

The general layout for manufacturing granulated agricultural lime under both basic and medium investments is as illustrated in Figure 4-1 below.

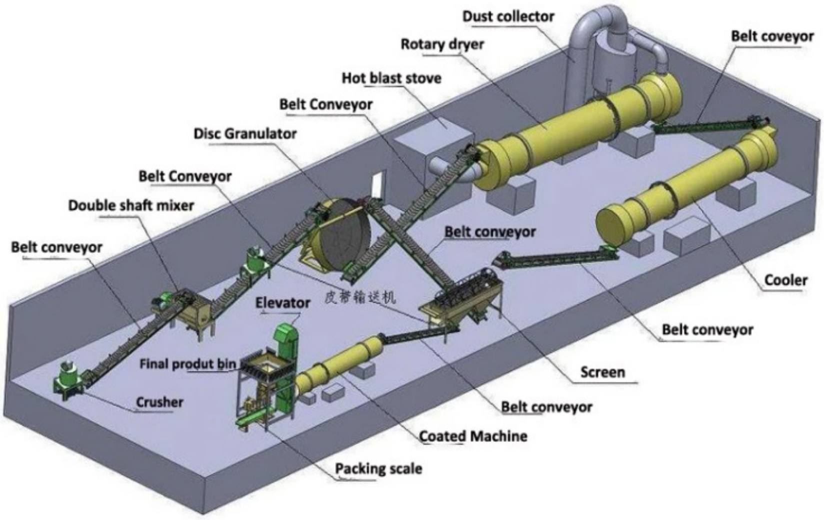
Figure 19: General layout for a basic to medium lime granulation investment



Source: Modified from Henan Hongxing Mining Machinery Co., Ltd

The general layout for manufacturing granulated lime in the high investment option is as presented in Figure 4-2.

Figure 20: General layout for a high investment lime granulation factory



Source: Henan Hongxing Mining Machinery Co., Ltd

The above investments assume that this will be adopted by manufacturers already processing powdered lime. While for making granular, the limestone powder size should be at least 80% less than 150microns (0.15mm) and 65% less than 45microns (0.45mm), factories experience is that 80% should be less than 75micron will be better at pelletizing. After Jaw crusher in the existing factories, 25mm lumps will be gotten. Further milling produces 45-150micron powder. These product need to be fed into smaller mills like the MTW mill, after which, 75micron powder will be got and this will then feed into Disc Granulator to get -4mm granular as a product. The MTW175 or MTW138 mill processes limestone to get 80% less than 75micron powder, then pelletizing will give 4mm granular.

To generate granules, mined limestone is first crushed into a fine powder. If necessary, a rotary dryer is used to dry the mined limestone before it is crushed. Next, a raw material feed bin is used to introduce the crushed limestone to the pelletization process. A mixer uses an intense spinning action to combine the limestone and binder, resulting in a densification within the material and a reduction of air and water volume between particles. While pin mixers are not always used, systems employing this limestone processing equipment have a higher throughput, use less binder, and yield more pellets in the desired final size range.

Secondly, the limestone mixture is fed onto a disc pelletizer (pan granulator) where it undergoes tumble growth agglomeration. If a pre-conditioning step were not utilized, this is where the pelletizing process would begin. The limestone builds and grows gradually as it rotates on the disc, with material and moisture being fed at a controlled rate.

The limestone pelletizing process adds moisture to the pellets, making, at times, drying a necessary step before storing or bagging the product (But this in some cases is not done like when dealing with limestone). Rotary dryers are a common drying choice due to their efficiency and ability to handle a high amount of volume and variability in feedstock. Flights within the dryer lift and cascade the limestone pellets as they travel through the dryer's rotating drum, creating an effective drying motion, while also preventing clumps.

If cooling is required (and at times is not), a rotary cooler is commonly used. This equipment provides the same lifting and cascading motion as a rotary dryer, but reduces the temperature of a product using a counter-current air stream. Once the material is dried and/or cooled, the limestone pellets are screened by size. Pellets over or under the desired size are recycled back into the limestone pelletizing process while optimally sized limestone pellets are bagged and/or stored

There is possibility of introducing a bucket, a hopper and feeding system to the mills. This will however, depend on existing facilities at the existing lime plant. This has been factored in the financial analysis.

5.2.2 Extra costs- Investment and OPEX

The study foresees additional capital requirements for a pelletizing of lime to make granulated lime. In developing our 2 different models under which an already existing investor in the agricultural powder lime would develop their capacity to manufacture granulated lime, we have established the different capacities which would ideally attract investors.

From the study carried out, the current market demand is approximately 150,000MT (Section 3.5.1) for which we have reviewed the costing of lime powder granulation as a single plant. With the growing demand of lime in the market, an investor can opt to produce 1/3 of this requirement at 50,000MT or develop capacity of manufacturing the whole demand of 150,000MT. We have therefore looked at the 30% capacity as a model that could be replicated in various regions by existing players depending on their location. This would suit those persons in different agricultural zones that have limestone deposits and within reach of the farming regions taking into account that transport of limestone is a costly. Working on this two different models provides us with a basis of establishing the projected costs and volumes that would ensure prices of the products are kept low and the inherent costs of establishing the extra capacity of granulating the lime are recouped. The modeling exercise therefore assumes that the manufacturer will obtain their coarse lime from their own production line at the ex-factory price of Kshs 5,000 per tonne. This cost therefore takes into account that the manufacturer has already built in costs for their existing infrastructure, margins and labour etc.

Manufacturers interviewed indicated that that the cost of 1 Metric tonne is between USD 40 and USD 60 meaning that we can take an average of USD 50 as the cost of the powder lime that would need to be granulated. Our model looks at the equipment that would be required to have a fully-fledged granulation plant. In terms of pricing of the granulated lime, we have reviewed the costing at different nodes of the agricultural lime value chain and taking consideration of the margins and costs of the investors, identified that pricing of Kshs 6,500 per tonne is most feasible.

Table 18: Estimated costs for granulation plant equipment under the 2 models

Estimated costs for Granulation of Lime					
Model		**Model 1**		**Model 2**	
Production Level		**150,000MT/Year**		**50,000MT/Year**	
Production capacity of Equipment per hour		**40-50MT/Hr-medium -High investment**		**10-15MT/Hr, Small-medium scale investment**	
Cost category	**Currency**	**Equipment required**	**Estimated cost**	**Item**	**Estimated cost**
FOB Price	USD	**Zenith PQ5000 Pelletizing Machine 40t/h**	175,542	**Pelletizing machine, Alibaba, Henan Hongxing Mining Machinery Co., Ltd; 15-18 tonnes/ hr Dimensions 3.7×2.7×3.3m, 11KW**	25,000
Shipping & Ins	USD		21,943		3,125
Excise Duty, VAT & Taxes	USD		26,331		3,750
	USD		223,816		31,875
Transport & Handling Costs	USD		11,191		1,594
	USD		235,007		33,469
USD/KES Exchange	108		25,380,740		3,614,625
Rounding off	KES	**Total**	**25,400,000**	**Total**	**3,600,000**
Construction	KES	**Building work**	2,500,000		1,500,000
Labour	KES				
Rounding off	KES	**Total**	**2,500,000**	**Total**	**1,500,000**
FOB Price	USD	**2 Double position particle packing machine - Zenith**	34,232	**Zenith Packing Machine**	16,119
Shipping & Ins	USD		4,279		2,015
Excise Duty, VAT & Taxes	USD		5,135		2,418
	USD		43,646		20,552
Transport & Handling Costs	USD		2,182		1,028
Total	USD		45,828		21,579
USD/KES Exchange	108		4,949,433.72		2,330,566
Rounding off	KES		**4,950,000**		**2,340,000**
Installation, Materials & Labour	KES		1,237,500		585,000
Rounding off	KES		1,240,000	Rounding off	590,000
Total	KES		**6,190,000**		**2,930,000**
FOB Price	USD	**6 belt or screw conveyors**	32,825	**4 belt conveyors 10 - 20m lengths, average US$4700 -EMCC**	18,800
Shipping & Ins	USD	**From MTW215-Z**	8,206		4,700
Excise Duty, VAT & Taxes	USD		5,744		3,290
Total	USD		46,774		26,790
Transport & Handling Costs	USD		4,677		2,679
Total	USD		51,452		29,469
USD/KES Exchange	108		5,556,775		3,182,652
Rounding off	KES		**5,560,000**		**3,200,000**
Installation, Materials & Labour	KES		1,390,000		800,000

Estimated costs for Granulation of Lime					
Model		**Model 1**		**Model 2**	
Production Level		**150,000MT/Year**		**50,000MT/Year**	
Production capacity of Equipment per hour		**40-50MT/Hr-medium -High investment**		**10-15MT/Hr, Small-medium scale investment**	
Cost category	**Currency**	**Equipment required**	**Estimated cost**	**Item**	**Estimated cost**
Rounding off	KES		1,390,000	Rounding off	800,000
Total	KES		**6,950,000**		**4,000,000**
FOB Price (2units)	USD	**12 belt and screw conveyors and bucket elevator motors (5.5KW @400), 5 machine motors (20-200KW@ 850) -Amazon**	12,300	**8 conveyors and bucket elevator motors -5.5KW @400, 5 machine motors (11-20KW@ 850)-Amazon**	7,450
Shipping & Ins	USD		2,306		1,397
Excise Duty, VAT & Taxes	USD		2,153		1,304
Total	USD		16,759		10,151
Transport & Handling Costs	USD		1,676		1,015
Total	USD		18,435		11,166
USD/KES Exchange	108		1,990,940		1,205,894
Rounding off	KES		1,990,000		1,210,000
Installation, Materials & Labour	KES		497,500		302,500
Rounding off	KES		500,000		300,000
Total	KES		**2,490,000**		**1,510,000**
FOB Price (1unit)	USD	**Bucket Elevator - Zenith**	19,457	**Bucket Elevator, 15MT/hr - Zenith**	6,136
Shipping & Ins	USD		2,432		767
Excise Duty, VAT & Taxes	USD		2,919		920
Total	USD		24,808		7,823
Transport & Handling Costs	USD		1,240		391
Total	USD		26,048		8,215
USD/KES Exchange	108		2,813,190		887,174
Rounding off	KES		**2,814,000**		**888,000**
Installation, Materials & Labour	KES		703,500		221,857
Rounding off	KES		704,000		222,000
Total	KES		**3,518,000**		**1,110,000**
FOB Price (1unit)	USD	**Other Item-Control cabinet 630KW**	21,200	**Control cabinet 350KW, (estimate)**	12,000
Shipping & Ins	USD		1,634		925
Excise Duty, VAT & Taxes	USD		3,710		2,100
Total	USD		26,544		15,025
Transport & Handling Costs	USD		2,654		1,503
Total	USD		29,199		16,528
USD/KES Exchange	108		3,153,472		1,784,984
Rounding off	KES		3,154,000		1,785,000
Installation, Materials & Labour	KES		787,223		445,598
Rounding off	KES		788,000		446,000

Estimated costs for Granulation of Lime					
Model		**Model 1**		**Model 2**	
Production Level		**150,000MT/Year**		**50,000MT/Year**	
Production capacity of Equipment per hour		**40-50MT/Hr-medium -High investment**		**10-15MT/Hr, Small-medium scale investment**	
Cost category	**Currency**	**Equipment required**	**Estimated cost**	**Item**	**Estimated cost**
Total	KES		**3,942,000**		**2,231,000**
FOB Price (1unit)	USD	**Mill - 150 microns to 80% less than 75 microns - Zenith MTW175G mill system**	180,930	**1 Crusher Mill - 150 microns to 80% less than 75 microns - Zenith MTW138 Z mill system,**	115,151
Shipping & Ins	USD		27,140		14,394
Excise Duty, VAT & Taxes	USD		26,331		17,273
Total	USD		223,816		146,818
Transport & Handling Costs	USD		11,191		7,341
Total	USD		235,007		154,158
USD/KES Exchange	108		25,380,740		16,649,107
Rounding off	KES		25,400,000		16,700,000
Installation, Materials & Labour	KES		7,620,000		5,010,000
Rounding off	KES		7,620,000		5,010,000
Total	KES		**33,020,000**		**21,710,000**
FOB Price (1unit)	USD	**Rotary screen - EMCC**	24,000	**Rotary screen - EMCC**	12,000
Shipping & Ins	USD		2,916		1,458
Excise Duty, VAT & Taxes	USD		3,499		1,750
Total	USD		29,742		14,871
Transport & Handling Costs	USD		1,487		744
Total	USD		31,229		15,614
USD/KES Exchange	108		3,372,732		1,686,366
Rounding off	KES		3,380,000		1,690,000
Installation, Materials & Labour	KES		996,641		498,321
Rounding off	KES		1,000,000		500,000
Total	KES		**4,380,000**		**2,190,000**
	USD	**1-Bucket elevator to mill**	19,457	**1-Bucket elevator to mill**	**6,136**
	USD	**1 - Hopper for MTW215 mill**	4,864	**Hopper and vibrating feeder for MW138 (depends on existing system) Zenith**	2,303
	USD		2,017		
FOB Price (the 3 unit)	USD	**1-Vibrating feeder**	**26,338**		**8,439**
Shipping & Ins	USD	**(depends on existing system)**	3,378		2,110
Excise Duty, VAT & Taxes	USD	**Source Zenith**	4,053		1,239
Total	USD		34,451		10,534
Transport & Handling Costs	USD		1,723		527
Total	USD		36,174		11,060
USD/KES Exchange	108		3,906,748		1,194,509

Estimated costs for Granulation of Lime					
Model		**Model 1**		**Model 2**	
Production Level		**150,000MT/Year**		**50,000MT/Year**	
Production capacity of Equipment per hour		**40-50MT/Hr-medium -High investment**		**10-15MT/Hr, Small-medium scale investment**	
Cost category	**Currency**	**Equipment required**	**Estimated cost**	**Item**	**Estimated cost**
Rounding off	KES		**3,910,000**		**1,195,000**
Construction	KES		-		-
Installation, Materials & Labour	KES		1,154,443		352,977
Total	KES		1,154,443		352,977
Rounding off	KES		1,155,000		353,000
Total	KES		**5,065,000**		**1,548,000**
FOB Price (1unit)	USD	**Material and adhesive mixer**	76,000	**Material and adhesive mixer**	32,000
Shipping & Ins	USD		9,234		3,888
Excise Duty, VAT & Taxes	USD		11,080		4,665
Total	USD		94,183		39,656
Transport & Handling Costs	USD		4,709		1,983
Total	USD		98,892		41,639
USD/KES Exchange	108		10,680,318		4,496,976
Rounding off	KES		10,690,000		4,500,000
Installation, Materials & Labour	KES		3,156,030		1,328,855
Rounding off	KES		3,160,000		1,330,000
Total	KES		**13,850,000**		**5,830,000**
Lump sum	**KES**	**Provision for spares, other equipment and contingency**	**5,000,000**		**2,000,000**
	TOTAL		**112,305,000**	-	**50,159,000**

NB: These costs were obtained from quotations and discussions with manufacturers in China.

5.2.3 Plant design, equipment acquisition and installation timelines

It is envisaged that the planning, design, approval, sourcing of equipment, procurement, shipping, transportation, installation, training of staff, commissioning would take approximately 7 1/2 months broken down as follows:

Table 19: Plant set-up timelines

Item	Description	Timeline
1	Plant design and drawings	1 month
2	Approvals and licensing	1 months
3	Resource mobilization (Financing, human resource recruitment etc.)	1 month
4	Marketing and distribution planning/networks	2 weeks
5	Equipment acquisition and buildings	1 month
6	Shipping and transportation	1 month
7	Equipment installation, testing and commissioning - cost included in cost of equipment	1 month
8	Training costs - included in plant equipment cost	2 weeks
	Total Time	**7 months**

The above timelines would enable the manufacturer obtain the necessary designs, approvals and procure the equipment in good time prior to installation and commencement of production. With an already existing workforce, it would not be difficult to train and enhance capacity of their skills set to operate the new plant whilst also recruiting any new staff. Most suppliers of capital equipment offer installation and training for new installations as well as after sales service to guarantee seamless operation of the new plant equipment.

5.2.4 Operational costs

In establishing the viability of a lime granulating plant to add on the existing infrastructure, we developed a model to enable us review the costs that would facilitate the operationalization of the plant. Key among the costing was the above equipment whose source is mainly China for purposes of our model. In addition, the cost of the equipment has taken into consideration freight, insurance, import taxes, VAT, transport, installation costs as well as costs of the plant floor space required. It should be noted that we have limited our costing to the expansion of existing facilities already manufacturing agricultural lime in powder form.

In all cases, and in addition to investment costs, power consumption is noted to be one the major operation costs for granulation. The power costs for the different scenarios are as shown, in Table 4-4.

Table 20: Electricity costs under different scenarios using KPLC tariffs – Nov 2020

	Plant Capacity	Kwh	Tonnes per hour	Kw rating	Cost of power
Model 1	150,000MT	1,890,000	50	630	35,244,064
Model 2	50,000MT	1,166,667	15	350	21,978,860
Model 2	50,000MT	1,166,667	15	350	21,978,860

In addition, it is expected that during the granulation process, a binding agent such as molasses is going to be used. Binding is required to bond the lime powder particles and allow handling of the pellets until they are applied to the soil without degradation or breakdown during storage or transportation. The cost of the binding medium is estimated at Kshs 30.0Million the rate of USD 2 per tonne. This works out to Kshs 30Million per annum for production of 150,000MT under Model 1. The cost of the binding medium (molasses) or lignosulfonate is assumed to be produced in close proximity to the granulated lime manufacturing plant to keep the transport costs low as long haulage of medium would significantly add to the total cost of binding agent.

5.2.5 Funding of the Investment

After analyzing the additional needs to set up a granulation plant, we envisage a funding requirement of Kshs 155,188,474 to cater for the equipment required as well as working capital. In our financial analysis, the investor will contribute Kshs 25,118,474 and the balance of Kshs 130,000,000 could be sourced from a long-term financier. In the model used to review the economic viability, we have assumed that a commercial loan of Kshs 130,000,000 will be availed at an interest rate of 12% for a period of 8 years.

5.2.6 Economic analysis and returns

Annual Turnover

The tonnage for purposes of modeling is expected to grow by a modest 5% per annum so as maintain plant capacity within the recommended manufacturers limits. Any excess requirement would only be met through variation of working hours by way of overtime and a 2nd shift where necessary. Annual sales turnover for Model 1, for the first 3 years are as shown in the Table below. These will increase from Kshs. 1.17 Billion in year 1 to Kshs. 1.22Billion in year 2 and further to Kshs. 1.28Billion year 3.

With the turnover of 150,000MT projected, the net income before taxes is estimated to be Kshs. 61.8 million, decreasing to Kshs. 48.3 million in the 2nd year after providing for bad debts which would arise from efforts to market the product in the 1st year. In the 3rd year, despite provision for bad debts at 2% of sales, the net income before tax improves to Kshs 54.6. The model has not considered the capital allowances that would be entitled to the investor so as to reflect a normal business scenario without any incentives that would give an entrepreneur a false sense of success.

Table 21: Revenues and Expenses in Model 1

Projected Revenue and Expenses			
Revenue	**2021**	**2022**	**2023**
Production – Granulated Agri Lime (MT)	150,000	157,500	165,375
No of bags – 25Kg (000)	6,000	6,300	6,615
	Kshs	Kshs	Kshs
Sale – Ex Factory Price	163	163	163
Sales Revenue (000)	975,000	1,023,750	1,074,938
Total Revenue (000)	1,170,000	1,228,500	1,289,925
Cost of Goods Sold	125	125	125
Total Operating Expenses	122,784,064	128,480,467	134,450,027
Income (Before Other Expenses)	**92,270,936**	**97,554,533**	**103,119,373**
Other Expenses			
Amortized Start-up Expenses	500,000	500,000	500,000
Depreciation	13,850,625	13,850,625	13,850,625
Interest – Commercial Loan	16,068,778	14,345,503	12,403,674
Bad Debt Expense	-	20,475,000	21,498,750
Total Other Expenses	**30,419,403**	**49,171,128**	**48,253,049**
Net Income Before Income Tax	**61,851,533**	**48,383,404**	**54,866,324**
Income Tax	18,555,460	20,657,521	22,909,522
Net Income/Loss - Kshs	**43,296,073**	**27,725,883**	**31,956,802**

Given the above revenues, the return on equity (ROE) and on Assets (ROA) is shown in Table 4-6 below while the analysis of the NPVs and IRRs is as shown in Table 4-7 below.

Table 22: Financial Ratios - Model 1

	Year 1	**Year 2**	**Year 3**
Return on Equity (ROE)	83.1%	34.73%	28.59%
Return on Assets	21.9%	13.2%	14.1%

Table 23: NPV and IRR – Model 1

NPV & IRR FOR GRANULATED LIME INVESTOR										
		Base Year - 2020	2021	2022	2023	2024	2025	2026	2027	2028
Initial Outlay		(148,805,000)								
After-Tax Cash Flow			38,433,885	25,021,670	27,223,572	28,584,751	30,013,989	31,514,688	33,090,423	34,744,944
WACC										
12%	PV		34,315,969	19,947,122	19,377,201	18,166,126	17,030,743	15,966,322	14,968,427	14,032,900
Risk Free Rate										
6%	SUM of PV		153,804,810		IRR	13%				
	Less: Initial outlay		(148,805,000)		Modified IRR	12%				
	NPV		4,999,810							
	Base Year - 2020		2021	2022	2023	2024	2025	2026	2027	2029
Cummulative Cash Flow		(148,805,000)	(110,371,115)	(85,349,445)	(58,125,872)	(29,541,121)	472,868	31,987,556	65,077,978	99,822,922
Fraction		-	-	-	-	-	0.98	0.02	0.97	1.87

Payback period

In Model 1 with production capacity of 150,000MT and investment of KES 148 Million, the calculations on the cumulative net cash flows for the period 2021 to 2028 have been carried out based on projected sales. The investment payback period works out to be 4 years and 11 months as follows:

Table 24: Investment payback period Model 1

Investment payback period Model 1			
	Kshs	Kshs	
Total Investment	(148,805,000)	(148,805,000)	
			Years
Net Cash flow year 1	38,433,885	(110,371,115)	1
Net Cash flow year 2	25,021,670	(85,349,445)	1
Net Cash flow year 3	27,223,572	(58,125,872)	1
Net Cash flow year 4	28,584,751	(29,541,121)	1
Net Cash flow year 5	30,013,989	472,868	0
Payback period - Years	**4.984**	**Years**	4

In Model 2 where investment is on a plant with an output capacity of 50,000MT per annum, the with outlay of Kshs 57,659,000, our calculations indicated that the size of plant and sales volume from production would not justify the investment owing to a negative IRR of -14% with the WACC being 12%.

In model 3 where we adjusted the granulated lime sales price per ton from Kshs 6,500 to Kshs 7,000 per ton on the plant with 50,000 MT capacity, the model indicated that the operation was viable with a payback period of 2.63years. The IRR works out to 36% with the ROE being 67.63% in year 1 and 34.76% and 27.7% in year 2 and 3 respectively. The NPM is 6.96% in year 1, 5.22% in year 2 and 5.48% in year 3

In summary the establishment of the lime granulating plant is feasible as long as the uptake of production in terms of sales is guaranteed, owing to the high cost of capital equipment.

5.2.7 Distribution and Retail of Granulated Lime

Following on the projected pricing of granulated lime from manufacturers at the rate of Kshs 6,500 per tonne or Kshs 6.5 per Kg in model 1 of this study, the projected price of granulated lime from a distributor is projected to be Kshs 475 per 50Kg bag inclusive of Kshs 2.00 transport cost per Kg and Kshs 50 as profit for the distributor. The transport cost is based on current transport costs levied by transporters in Kenya for Agricultural lime. For a distributor who sells 500 bags of granulated lime (50Kg bags) in a month, their gross profit on granulated lime would be Kshs 25,000.

Retailers in most regions put a markup of between Kshs 50 and Kshs 100 per bag of 50Kg. They would also incur transport costs of Kshs 2 per Kg. The retail price would then be between Kshs 625 and Kshs 650 per 50Kg bag of granulated lime. While the study indicated that there was low demand of lime at retail level outlets such as agrovets, with enhanced awareness it is expected that demand will pick up. While the pricing of the agricultural lime powder and granulated lime appear similar in profit margins at the onset, it is expected that with the benefits of granulated lime being enumerated in a more pronounced method, demand will increase resulting in improved sales for the retailers and distributors.

Leveraging on existing inputs distribution channels will create ease of entry for granulated lime. As established section 3.4.2 smallholder farmers are willing to pay more for a working solution and hence the need to intensively demonstrate usefulness of the benefits of granulated lime compared to powder lime.

With planned production of 150,000 metric tonnes of granulated lime, the number of 50Kg bags would be 3.0Million. To distribute these to farmers, it would require 20 cooperatives with membership of 100 each with and 75 distribution units with each farmer collecting 10 bags with capacity of 2 seasonal crops.

5.2.8 Current cost of agricultural lime compared to imported granulated lime and potential savings in Foreign Exchange

Currently, imported granulated lime consumption is estimated 4,000MT per annum. The estimated price per tonne of the imported granulated lime is USD 400. With taxation and related importation costs, the retail price of the granulated lime is approximately Kshs 1,400 for a 25Kg bag. This means that the country spends an estimated USD 2,074,074 (Kshs 224,000,000) per annum importing the granulated lime. With projected growth in the use of agricultural lime expected to grow through creation of awareness on the benefits of liming to increase production, the foreign exchange required for granulated lime will continue to rise.

Table 25: Current annual usage of granulated lime and cost to farmers at retail level

Item	Cost per kg	Cost per kg	Packaging size	Average cost 50kg bag	Current usage	No. of bags	Cost	Cost
	Kshs	USD			MT		Kshs	USD
Imported Granulated Lime	1,400	13	50Kgs	2,800	4,000	80,000	224,000,000	2,074,074
Local Powder Lime	10	0.093	50Kgs	500	137,000	2,740,000	1,370,000,000	12,685,185

Were the granulated lime production process to be done locally, the country would save USD 2.07Million per annum. Local production would also see the price of granulated lime drastically drop from Kshs 2,800 to Kshs 650 per 50Kg bag (section 4.2.6 above). Apart from savings in foreign exchange savings, local production would create jobs for the numerous unemployed youth in direct and indirect employment in the extraction, transportation, processing, packaging and distribution of the granulated lime produce.

Table 26: Projected cost to farmer of locally manufactured granulated lime at retail level

Item	Cost per kg (Kshs)	Cost in USD/ kg	Packaging size	Average cost 50kg bag (Kshs)	Current usage (MT)	No. of bags	Cost in Kshs	Cost in USD
Granulated agricultural lime	13	0.12	50Kgs	650	150,000	3,000,000	1,950,000,000	18,055,555

6

POLICY ISSUES ON AGRICULTURAL LIME

6.1 Current scenario

Owing to the fact that lime use in Kenya is still low, there is a lack of policies and regulations on the agricultural lime production for the Kenyan Market. This is as opposed to the other related sectors such as fertilizers where regulation is managed by multiple agencies through the Fertilizers and Animal Foodstuffs Act, Cap 345, under the Ministry of Agriculture, Livestock and Fisheries (MOALF). The said act was passed to, "regulate the importation, manufacture and sale of agricultural fertilizers and animal foodstuffs and substances of animal origin intended for the manufacture of such fertilizers and foodstuffs, and to provide for matters incidental to and connected with their use…"[35].

6.2 Key policy challenges

The key policy challenge in the lime industry is the lack of clear quality guidelines and standards for lime. There are disparities in the terminology and application among players in the industry. Some call pelletized lime granulated with some importers calling such products substandard lime which has not gone through a standard granulation process. Owing to different blending methods and mixes, there are no companies that have similar or related products. The competition in market share is stiff and undercutting in pricing is prevalent. The presence of many lime products/blends have created weaknesses in availability of standard products to both small scale and large scale farmers. It is also not clear as to what percent of lime should be present in blended products. The farmers are more aligned to the respective manufacturer brand who offers technical and advisory services not withstanding quality of the products.

Related to quality of lime is the dosage of application. While a number of recommendations on lime use application dosage exist following various field trials[36], grey areas still exist as to the quantities to be applied per unit area of land under different soil types, different crops and different acidity levels[37]. There are also grey areas with regard to how long reapplication of lime should take. The best timing and approach to lime application is not clear, leaving farmers confused. Given that no standard exists for granulated lime, KEBS and relevant department should initiate the development of specific standard for granulated lime

On lime awareness and demand acceleration, there lacks national wide awareness creation platforms and funding opportunities[38]. For example, and as compared to fertilizers, the government (National or County), does not have set guidelines for lime subsidies.

6.3 What is needed

Kenya Bureau of standards needs to work with industry players to come up with parameters necessary for categorization of the lime products in the market. There is need for standards that spell out the different products in the market, based on active ingredients rather than brand names which confuse customers/farmers. Some lime based products have little lime, but without standards on percentage of lime or other ingredient, it is difficult for farmers to establish if what they are purchasing is quality. Researchers, practitioners, manufactures and development partners can support the government of Kenya to come up with clear policy guidelines and standards for lime use whether the powdered or granulated type of lime.

The government subsidy programme should also be enhanced through inclusion of soil improvement products that can easily be adopted by the farmers. Among the key products to be promoted would be lime products for soil amelioration. In addition, soil testing is very low and considered expensive, support for soil testing would guide the use of the right types and quantities of fertilizers, lime and seeds; thereby increasing farm level productivity. Drivers to increasing productivity lie in provision of high-quality inputs, ensuring affordability and access to credit, and training on the correct farming practice.

Given the current demand of lime and granulated lime, the government needs to provide incentive and conducive environment through policies and legislation to support the development and growth of granulation sector. The costs of setting up a lime granulation plant were found to be high and the investors need to be assured that policy changes would enable them recoup their investments in the plant by having a ready market to absorb the granulated lime produced. This is especially necessary to cushion the manufacturers during the early stages of investment as the demand grows. In the study results analysis, it was noted that though 2o.2% of sampled farmers are currently using lime, information on when and how to apply it is still unclear. This calls for a policy shift to disseminate information on lime use prior to the planting season so as to correct the soil pH as necessary. On critical factor was the fact that small holder farmers are aware of soil testing but did not always have it carried out owing to the inherent cost of soil testing.

7

CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

Overall, the assignment comprised an analysis of two key components i.e market feasibility and economic feasibility analysis for granulated lime. Owing to the low awareness, supply and use of granulated lime, the study adopted an analysis of the currently available powdered lime and used current data to project the future potential demands and supply for granulated lime. It also estimates the returns and the value of investments needed both at the farm level and at the manufacturing level.

While awareness of agricultural lime was noted to be relatively high (approximately 60%), agricultural lime use was relatively low as only 20.2% of respondents (farming households) were using lime. The level of farmers' awareness was considerably high especially in Aberdares (95.7%), Mt. Kenya (67.9%), and North rift (62.3%). In comparison, almost all farmers (97.7%), across all the regions used different types of fertilizers. Coast had the lowest reported fertilizer usage at 83.3% with all the other regions recording more than 90%. This implies that there is still need to create awareness of agricultural lime. Currently, fellow farmer and farmer cooperatives are the major sources of information on agricultural lime for between 18% and 53% of farmers while agricultural officer reach between 2.7% and 25% of farmers in the various regions.

Lime was mainly used in maize, coffee and in some few cases in sugarcane. Lime use in coffee averaged 336.9 kgs per acre (832 kgs/ha) ranging from a low of 50kgs to a maximum of 2 MT/acre while lime use in maize was lower than that of coffee and averaged 105.9kgs per acre (262 kgs/ha). Notably, the amounts of lime currently used are still way lower than the recommended amounts.

Private agro-dealers played a major role in inputs supply. For a majority of farmers (62.9%), agro-dealers were the main source of fertilizers while farmer producer organizations such as cooperatives and farmer groups were a source for 17.8% of respondents. Similarly, farmer's sourced lime from majority of the farmers accessing lime purchased the agrovets/agro-dealers (52.3%) and Farmer Producer Organizations (34.1%).

The current national demand is estimated at approximately 187,000 MT annually. Three major demand centres were established comprising Central (Mt. Kenya and Abedares region), Rift Valley (South, Central and North rift), and Western (Western and lake regions). These demand centres are driven by lime use in the three key crops namely coffee, maize and sugarcane respectively. This also indicates areas where lime manufacturing and granulation businesses as well as distribution businesses would have higher potential.

Future demands for lime are estimated to increase to 319,000 MT in the next 5 years and then to 532,000 MT in ten years' time. Key drivers to increased demand would be increased awareness, availability and granulation which increase usability (ease of use) of lime compared to the powdered form.

Currently, agricultural lime is available in powdered form. Out of those that reportedly using lime in their farms, 98.2% used powdered form of lime (ground lime) and 1.8% used granulated lime. Only 1.1% of farmers are aware of granulated lime but 67.9% would be willing to use granulated lime in the future, but 33.9% would still prefer to stay with the powdered lime. This indicates the likely high demands for granulated lime in future. Indeed farmers are willing to pay up to Kshs. 30 per kg for the granulated lime.

On lime distribution, the study identified a number of channels including manufacturers appointed stockists and distributors; retail agro-dealers; NGOs projects and programs; coffee cooperative societies; and County government's subsidy programs. Lime was considered to be generally affordable, implying that prices are unlikely to be a hindrance to lime use. Retail prices from stockists ranged from Kshs. 350 to Kshs. 500 per 50 kg bag and Kshs. 600 to Ksh. 750 per 50kg bag from retail agro-dealers.

A few grey areas still remain with regards to lime use. There lacked a standardized recommendation on the amount of lime to be applied per unit area of land as recommendations ranged from a low of 0.5MT/ha to 6MT/ha. It is not also clear whether lime should be applied in different quantities for different crops or how much lime should be applied to correct soils with a certain acidity (pH) level. The timing of lime application (before planting, before ploughing, during planting, after planting etc.) is not clear. The best method of application (broadcasting or micro dosing) is also not clear; same to the time period it takes for a farmer to re-apply lime on the farm.

Majority of small-holder farmers do not maintain data on their lime use or even when and where they applied; they are therefore unable to quantify the change in yield as a result of the lime applied. Many farmers claim they see change but this are not measurable. Previous studies have estimated that yields in maize can increase by between 10 to 20%. This study shows some increases in maize crop yields in areas such as Bomet, Uasin Gishu and Trans Nzoia, with about 15% to 20% increases in yields. Analysis shows a positive difference in yields when lime is applied as compared to when lime is not applied. Results show that for maize yield increased by up to 83% when lime is applied, while for coffee yield increased by up to 62.9% per acre. It was difficult to establish the contribution of liming on the achieved crop yields given that most of the farmers who applied lime in their farms combined it with use of inorganic fertilizer and organic manures.

This study creates different lime use (or not use) scenarios to calculate potential economic benefits. Differences are notable in the NPV and BCR levels for farmers using lime and those that are not. Returns are generally high mainly because additional costs for purchasing lime are low and because farmers may still not be applying recommended amounts. In maize, economic returns were higher in scenario 3 where lime is applied by micro-dosing. This is attributed to low amounts of lime used and thus low costs for purchasing lime. Even in the short run, coffee farmers who apply lime would get revenues that are 6 times more than the costs incurred

On the supply side, it was noted that investments in lime granulation would require at least Kshs. 58 million for a 15T/hr granulation plant and Kshs. 148 million for a 50T/hr plant. With the projected increases in demand, such investments will attract positive returns and be able to pay back y in 2.63 years (Model 3) and 4.98 years (Model 1) respectively.

7.2 Recommendations

The success of the Kenyan granulated lime hinges on there being effective demand. There is need to create awareness on the benefits of lime application and more so granulated lime whose application is friendly to the small-scale farmers who may not have the sophisticated equipment that large scale farmers have access to.

The fact that lime is required in large quantities (up to 4MT/ha) is discouraging farmers from use of lime. Recommended quantities attract additional production costs of as much as Kshs. 24,000 per ha of land. This combined with limited credit makes prioritization of lime low among many competing financial needs. However, the additional yields and revenues achieved are able to cover the additional costs incurred. There is therefore need to consider subsidization of lime at the farm level at least to kick start farmers for the first time to apply recommended quantities of lime for them to achieve good returns.

Farmer's awareness on soil health and nutrition and lime and its advantages is still very low. There is need for departments of agriculture and other extension service providers to organize to have curriculum for farmer training to reduce haphazard and confusing extension messages in this area. More extension services by trained ministry staff both at National and local county level are required to ensure already mapped acidic soil areas receives advisory services on necessary interventions.

Knowledge and awareness is also required on the supply side. There is need for enhanced interventions to support agro-dealers, cooperatives and stockists to improve their knowledge on lime as well as their capacities to stock and distribute. Only in this way they will be able to make lime readily available and eventually increase uptake and productivity levels.

There lacks advanced soil testing labs around the country; with adequate and well serviced equipment. Most laboratories have broken equipment and turnaround time for results is very long. The national government and Counties should properly equip and calibrate the soil testing laboratories within their areas. The same should provide lime as a subsidy after mapping the soil acidity levels.

Grey areas that exist in lime use, timing, application methods, recommended quantities, yield responses and lime quality can be solved by undertaking coordinated research. There is need for funding of research organizations either by National government or donors to undertake crop response trials.

At the market level, lime quality and standard are lacking. There is need for policy on standards of the lime quality that meets the needs of the market differing only in rate of application. This will ensure that proper labelling is done to guide the consumers on usage. In effect, the policy will guide uniformity in labeling to avoid confusing the intended users. As a starting point, the Kenya Bureau of Standards and other relevant authorities needs to work with industry players to come up with parameters necessary for categorization of the lime products in the market. There is need for standards that spell out the different products in the market, based on active ingredients rather than brand names. The policy will enhance good practices by manufacturers, distributors, retailers and users in terms of uniformity of product quality, blending, labelling, storage, carriage, usage information. The policy should also spell out penalties for failure to conform to the policies as well as risk mitigation measures necessary to monitor continued compliance. The policies will also include periodic sampling of lime and lime based products in the field use, at distributor and retail level for purposes of quality and safety testing of the products. Disposal of packaging material used in lime use should be monitored at all levels to ensure safe disposal of used bags and or containers. Certificates of compliance should be regularly issued to manufacturers, distributors, retailers and users to ensure the good practices are adopted as part of measures to increase agricultural production.

Endnotes

1 KMT (2019). Enhancing market access and use of agricultural lime among smallholder farmers in Western Kenya region. Early Impact Assessment Report (Abridged Version)

2 It was reported that ground lime was available in various colors including white, grey and black. The color variations depend on the way the parent limestone material was formed (volcanic or sedimentary) and the presence of other compounds apart from calcium carbonate, such as oxides of manganese, phosphorus and iron (source: https://www.homalime.com)

3 One-acre fund (2014). Managing soil acidity. Phase 2 trial report

4 KARI (2002). Acidic soils in Kenya: Constraints and remedial options. KARI Technical Note No. 11 June

5 KMT (2019). Enhancing market access and use of agricultural lime among smallholder farmers in Western Kenya region. Early Impact Assessment Report (Abridged Version)

6 NB: For soils to turn acidic because of DAP use, it has to be over a long period of time and intensively used- Source KALRO

7 Esilaba. A.O. (2018). Overcoming Soil Acidity and Constraints through Liming and Soil Amendments. Proceedings of the Kenya Fertilizer Roundtable Conference; OCTOBER 16-17, 2018

8 Muindi et.al., (2016). Soil Acidity Management by Farmers in the Kenya Highlands (2016). Journal of Agriculture and Ecology Research International 5(3):1-1122519

9 One acre fund (2015). Managing Soil Acidity with Lime

10 Kirui K. P (2018). Effects of agricultural lime types on soil properties and maize (Zea mays l) performance in soils of Tharaka. Nithi County, Kenya (Msc Thesis)

11 Mallarino A. P and Haq M. U (2014). Evaluation of Agricultural Lime and Pelleted Lime to Increase Soil pH and Crop Yield (Unpublished- Iowa State University)

12 Also called Aglime, agricultural limestone, garden lime or simply liming. Agricultural lime is a soil amendment product used to condition soil by raising pH levels. It is made from crushed limestone that contains natural nutrients to promote healthy plant growth. When lime is added to agricultural crops, it dissolves and releases a base that counteracts or neutralizes soil acidity.

13 Calcium carbonate (Calcitic lime) is derived from deposits of primarily calcium carbonate while Dolomitic lime is derived from deposits of calcium carbonate combined with magnesium carbonate and contains much higher levels of magnesium.

14 Source: https://www.bakerlime.com/top-agricultural-benefits-limestone/

15 Source: https://www.gardeningknowhow.com

16 Enhancing Market Access and Use of Agricultural Lime Among Smallholder Farmers in Western Kenya Region- Early Impact Assessment Report- 2019

17 Kelvin Owino, Managing Soil Acidity with Lime (2015), One Acre Fund

18 Common lime recommendations range from 1.6 tonnes per acre or 4 tonnes per hectare

19 https://tradingeconomics.com/Kenya /imports/fertilizers;

20 Key local manufacturers of fertilizers include KEL Chemicals Ltd; Toyota Tusho and ARM- Mavuno fertilizer limited

21 eg. Calcipril; a product of Omya International that is distributed locally by Amiran Kenya

22 www.farmbizafrica.com/profit-boosters/1653-researchers-blend-fertilizers-to-boost-yields

23 Mostly in India and China

24 Notably, these considered themselves as unemployed despite being farmers; meaning they don't consider their farming as a commercial venture or a source of employment

25 While land sizes in Kirinyaga County was small averaging 1.28 acres, average land holding in Meru was 3.96 acres, raising the average to 2.53 acres.

26 These were mainly coffee cooperatives in Kirinyaga County

27 This was mostly in Nyeri where the County government provided subsidized lime to coffee farmers in 2018-2019 seasons. Each farmer received 2 bags (50kgs) at a cost of only KES 100 per bag. The charge of KES 100 per bag was only meant to cater for transportation costs. Distribution was done via coffee cooperatives.

28 It was reported that ground lime was available in various colors including white, grey and black. The color variations depend on the way the parent limestone material was formed (volcanic or sedimentary) and the presence of other compounds apart from calcium carbonate, such as oxides of manganese, phosphorus and iron (source: https://www.homalime.com)

29 It was not fully established whether any brands of granulated lime are available in the Kenyan market. Omya Kenya however, used to distribute granulated lime (that was imported from Germany) via Amiran Kenya network. This partnership has since ended.

30 Mangale et. al, 2016. Field And Laboratory Research Manual for Integrated Soil Fertility Management in Kenya

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32 It was unclear how farmers determined the most appropriate time when to apply lime

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