

FarmLime: Low-cost lime for small-scale farming

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Abstract

In the less developed parts of southern Africa, where agriculture is crucial in daily survival, agricultural lime is often difficult to obtain. This is due to the scarcity of production sites, high transport costs and inadequate support for farmers from government extension services. In Zambia there are upwards of 700,000 small-scale farmers who struggle to farm on acid soils and as a result have poor crop yields. They cannot afford to use agricultural lime, which would solve the problem and as a result are trapped in a cycle of poverty. In an attempt to address this problem the UK research project 'FarmLime', based in Zambia, investigated a means of producing affordable agricultural lime using simple, locally available technology. Dolomite suitable for agricultural lime occurs throughout Zambia including those farming districts with acidic soils. It is estimated that small-scale production using partly manual methods could produce agricultural lime for US\$25-30 per tonne. Demonstration crop trials were successful in demonstrating the benefits of using agricultural lime to small-scale farmers. Where the price of maize is high and the cost of lime is low the economic benefits of its use are high. However, even if there is a demonstrable economic benefit, the use of agricultural lime will be constrained by the lack of cash in the rural economy; one potential solution to this could be bartering of crops for agricultural lime.

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Agricultural lime is a commodity taken for granted in most developed countries. Agricultural lime is used in farming as a soil conditioner to prevent acidification, provide a source of plant nutrients (calcium and magnesium) and improve the physical properties of the soil. In the UK it is produced in modern processing plants alongside aggregate and other products such as mineral fillers. The project 'FarmLime: Low-cost lime for small-scale farming' was funded by the UK Government Department for International Development (DfID). The aim of DfID research is to "alleviate poverty" through improved access to knowledge and technology, specifically by "enhancing the productive capacity (of less-developed countries) in an environmentally sensitive manner". The findings of a previous DfID research project 'Local development of affordable lime in southern Africa' concluded that agricultural lime could be produced on a small-scale from local dolomite within farming districts. The aim of the FarmLime project was to test these conclusions in the farming districts of Northern Zambia, which are broadly representative of farming in southern Africa.

Agricultural lime production & consumption in Zambia

Agricultural lime is available from five companies in Zambia, located in the main 'economic corridor' extending from Lusaka in the south to the Copperbelt in the north. Lilyvale Farm (Kabwe, Central Province) is a coffee plantation that also produces agricultural lime and represents the old style of operation, which was developed to serve the needs of the large agricultural estates. Minedeco Small Mines in Lusaka, is a former parastatal company that produces mineral fillers for local industry as well as a small volume of agricultural lime. Ndola Lime Ltd (Ndola, Copperbelt Province) is a large quick lime and hydrated lime plant that produces agricultural lime as a by-product 'dust' from the crushing plant. These operations represent the old nationalized industry established in the 1960s. However they now have to exist without state subsidies alongside more competitive rivals and as a result all are struggling. Uniturtle Industries (Z) Ltd in Lusaka, is a company that mainly produces decorative stone and has in the last few years expanded into production of mineral fillers, agricultural lime and stock feed. Hi-Qwalime Mining Ltd (Mkushi,

Central Province) is an operation dedicated to producing agricultural lime. These operations have been encouraged since denationalization of the state mining sector and have been funded by private investment with strong South African connections.

The current consumption of agricultural lime in Zambia is about 40,000 tonnes per year mostly by large-scale commercial farmers. This is a relatively low volume as the latent demand for agricultural lime is thought to be about 150,000 tonnes per year (Shitumbanuma & Simukanga, 1995). To achieve this level of consumption would require a dramatic increase in the use of agricultural lime, especially by small-scale farmers; however they do not have a tradition of using this agricultural input.

Socio-economic survey

Small-scale farmers who use agricultural lime can improve their crop yields, produce more food for their families and (potentially) generate some income. Surveys carried out by questionnaire returns & interviewing of small-scale farmers representative of farming districts in Zambia (Mitchell *et al* 1997; 2003) found that they do not use lime for the following reasons:

- Farmers are either unaware or unconvinced of the need for agricultural lime. Farmers receive little advice on the use of agricultural lime from agricultural extension workers (field workers providing advice and assistance to farmers), there is a lack of information regarding its quality and use, and poor packaging and labeling.
- The Ministry of Agriculture, Food & Fisheries and the University of Zambia both carry out soil testing for farmers. However, little soil sampling and testing is carried out for small-scale farmers because it is expensive and time consuming. Farmers do not know their soil pH and the amount of lime to apply.

- Agricultural lime is expensive and often the farmers do not have the cash to buy it. An alternative form of payment, such as bartering, could partly replace cash payment. Most of the producers are reluctant to supply the small volumes (50kg) required by small-scale farmers as they prefer to supply in large volumes to commercial farmers. Also, transportation is expensive, typically adding US\$1 per tonne per 10km traveled.

Government and NGO (Non-Governmental Organisation) food security programmes have attempted to stimulate the demand for agricultural lime by small-scale farmers without much success (Mengo 2002). However, this is probably the key to future development of small-scale farming in southern Africa.

Carbonate resource assessment

Most of the provinces in Zambia have carbonate resources (limestone and dolomite). However not all are suitable for the production of agricultural lime. The key parameters used to determine the suitability of these rocks as a source of agricultural lime are as follows:

- Neutralisation ability, expressed as the weight percentage Calcium Carbonate Equivalent (CCE) and often referred to as the Neutralisation Value (NV). This is the amount of calcite and/ or equivalent dolomite and is the key property in reducing soil acidity. A CCE value of 80% is considered to be a minimum for agricultural lime.
- Plant nutrient content, expressed as the weight percentage calcium oxide (CaO) and magnesium oxide (MgO). An MgO content of 6% is considered to be a minimum for agricultural lime (Tether & Money 1989).

- Ease of pulverization, otherwise known as the Grindability Index, is the weight percentage of fine particles generated in a milling trial. This indicates the hardness of the carbonate and, indirectly, the amount of energy required to produce agricultural lime of the required fineness.
- Agronomic effectiveness, otherwise known as the reactivity, is a measure of the rate at which agricultural lime neutralises soil acidity.

Dolomite is preferred for the production of agricultural lime as it contains both of the important plant nutrients (calcium and magnesium) and has a high neutralising ability (ARC Southern 1996). Dolomite samples from across Zambia were evaluated and many were found to have comparable technical properties with commercially available agricultural lime (Table 1).

Lime production research

Research was carried out to determine if agricultural lime could be produced on a small-scale, using appropriate technology and manual labour where appropriate. Commercial operations quarry, crush and grind carbonate rock to produce agricultural lime; typically with a particle-size distribution of 100% finer than 2mm, 60% finer than 400 μ m and up to 50% finer than 150 μ m.

Small-scale production of agricultural lime would require quarrying of carbonate rock involving manual bush clearing and loose soil removal, drilling and blasting, and manual loading and hauling of the extracted rock; with an estimated cost of US\$1.45 per tonne of rock extracted (see Table 2). Field trials were carried out to produce agricultural lime. Crushing of the dolomite to an appropriate size (10mm) for the milling stage was carried out manually using sledgehammers. This was found to be an expensive process as it was slow and labour intensive, costing up to US\$10 per tonne. As an alternative, a manually operated jaw crusher could be used to speed up the crushing process; it is estimated that this could reduce the cost of the crushing to less than US\$1 per tonne. The milling trials were based on the TD Hammer Mill (originally designed for

maize milling) which was modified for milling of dolomite. The mill is powered by a single-piston petrol engine, which is used to drive the mill hammers directly via the engine shaft. The rock is fed into the milling chamber via a launder and the ground material falls through a product sieve. The milling cost was estimated to be approximately US\$20 per tonne of (bagged) agricultural lime produced.

The estimated costs of producing agricultural lime using a small-scale operation are summarised in Table 2; these were based on Zambian labour and equipment costs. The overall cost is about US\$32 per tonne; use of a manual jaw crusher could reduce the production costs down to US\$25 per tonne.

Diversification & spontaneous uptake

The Zambian Poverty Reduction Strategy Paper (PRSP), produced by the Zambian Ministry of Finance and Economic Development (MOFED), focuses on measures to achieve strong sustained economic growth (5-8% pa) with enhanced agricultural productivity given the highest priority. Another key goal of the PRSP is diversification of the small-scale mining sector, currently dominated by gemstone mining, into industrial minerals. Industrial minerals form an integral part of the sustainable development of an economy as they are driven by genuine industrial needs and are more likely to be the basis of long-term economic activity. This compares with gemstone mining which often has problems associated with migrant labour and 'boom town' scenarios, cross border smuggling and illegal mining.

Diversification of an existing mineral producer, FRECA Mining & Manufacturing Ltd in Solwezi, has occurred through 'spontaneous uptake' of the agricultural lime production methods advocated by the FarmLime project following field trials of the modified TD Hammer Mill. FRECA employ small-scale miners to produce construction aggregate using traditional mining and crushing methods. Fires are set on the dolomite outcrops which when hot are doused with water to

promote cracking. The dolomite is then removed using picks and crowbars. The rock is crushed by hand using hammers and sieved to remove the dust, which is sold as agricultural lime (in 50kg bags) to local farmers. FRECA have fabricated a hammer mill, which they will use to produce agricultural lime from the crushed dolomite.

Crop trials

Demonstration crop trials were carried out to show farmers the benefits of using agricultural lime. The sites chosen for the demonstration trials were located in Mkushi district which has acid soils and a source of dolomite suitable for agricultural lime production. The agricultural lime used was that produced using the modified TD Hammer Mill. The amount required for the demonstration sites was based on the exchangeable aluminium content of the soil and the neutralising ability of the agricultural lime to be used. This was determined to be between 200 and 450kg per hectare. Each site was divided into ten plots - five for maize and five for groundnuts - including one with no lime, two with lime and two with double the amount of lime. The lime was added as either a 'spot application' (i.e. applied to the immediate vicinity of the plant only) or 'broadcast application' (i.e. spread over the entire plot).

The crops were planted according to the Zambian MAFF (Ministry of Agriculture, Food & Fisheries) recommendations for small-scale farmers. The farmer, his family and neighbours, tended the plots, which were revisited to monitor the progress the following year. The crops were harvested and data on grain weight are given in Table 3. The maize and groundnuts from the limed plots generally gave higher yields than the unlimed plots. During the agricultural lime demonstration farmers neighbouring the trial sites started to use agricultural lime; understanding this aspect of the crop trials will be important for future promotion of agricultural lime.

Cost Benefit Analysis

The benefits of using agricultural lime will largely depend on the economic factors, such as the cost of the lime and the increase in crop yields to the small-scale farmer. A cost benefit analysis was carried out to quantify the economic benefits for small-scale farmers in using agricultural lime. Farmers will directly benefit if the value of the additional crops produced exceeds the cost of the agricultural lime used. This can be quantified as a Value Cost Ratio (VCR) as follows:

$$\text{VCR} = \frac{(\text{Weight of additional crop produced}) \times (\text{Unit value of the crop})}{(\text{Cost of using agricultural lime})}$$

The UN Food & Agriculture Organisation (FAO) believes that for small scale farmers a VCR above 2 is required for uptake of new inputs (i.e. the value of the additional crops produced is at least double the cost of using agricultural lime). Value cost ratios were determined for several scenarios based on varying maize yields, maize price and input costs (Table 4). It is estimated that small-scale farmers should be able to increase their maize yields from their current average of about 1.5 tonnes per hectare per tonne of lime as follows:

- Extremely acid soil (pH <4.5) Increase maize yield by 5 tonnes per hectare
- Very acid soils (pH <5): Increase maize yield by 3 tonnes per hectare
- Acid soils (pH 5-6): Increase maize yield by 1.5 tonnes per hectare

The value of maize produced can vary greatly, from US\$200 per tonne (realised by commercial farmers close to maize mills and selling at the optimum time) to less than US\$50 per tonne (realised by small-scale farmers in remote locations selling as the need arises). The cost of agricultural lime is typically US\$20 ex-works (i.e. collected from the producer) and a further US\$1 is added per tonne for every 10 kilometres the lime has to be transported (this can multiply the

cost several fold for remote farmers). Two maize values (US\$50 and US\$110 per tonne) and two agricultural lime costs (US\$30 and US\$60 per tonne) were used in the calculations

The use of agricultural lime was found to be economically beneficial in most cases. The results show that farmers who live close to the source of their inputs, farm highly acid soils and can realise a high price for their maize will see the greatest improvements in their incomes.

Conclusions

Agricultural lime is a widely used commodity in the developed world. However, in less developed countries such as many in southern Africa this is not the case. Small-scale farmers are unaware or unconvinced of the need for agricultural lime and hence their use of lime is minimal.

Demonstrating the benefits of using lime is an important way to persuade farmers to use lime.

Once persuaded, they need a simple and cheap soil test to determine agricultural lime demand.

Agricultural lime should be made available to all small-scale farmers; for those who cannot afford to buy lime an alternative form of payment should be allowed, such as bartering.

There are ample resources of dolomite rock available throughout Zambia for agricultural lime production. The Neutralising Value (NV) and the plant nutrient content are the most important properties to determine in an evaluation of their suitability for use as agricultural lime. Small-scale production of agricultural lime would require quarrying (involving drilling and blasting), manual crushing and milling. The modified TD Hammer mill is capable of producing 1-2 tonnes of agricultural lime per day. The production cost was found to be relatively high (US\$32 per tonne); this cost could be reduced if a cheaper crushing method were employed.

Enhanced agricultural productivity and diversification of the small-scale mining sector are two key objectives of the Zambian Poverty Reduction Strategy. Spontaneous uptake of the agricultural lime production method by an existing small-scale operator in Solwezi met these objectives.

Demonstration plots (maize and groundnuts) were established in an attempt to convince small-scale farmers of the benefits of using agricultural lime. The highly acidic soil of the trial plots required lime addition of up to 500kg per hectare. The maize yield increased nearly threefold to 6.7 tonnes per hectare and the groundnut yield increased nearly seven fold to 320kg per hectare.

In most cases the use of agricultural lime by small-scale farmers will have economic benefits. However its use will depend on the small-scale farmer having the cash to purchase it and any significant increase in its use will probably require Government intervention. The key to uptake is demonstration of the benefits of using agricultural lime. The FarmLime project summary report is available as a download from: http://www.mineralsuk.com/free_downloads.html.

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Table 1 Comparison with commercially available agricultural lime

Sample site	Neutralisation	Plant nutrient		Ease of	Agronomic
	ability	content		pulverisation	effectiveness
	CCE	CaO	MgO	Grindability	Reactivity
	wt %	Wt %	Wt %	Wt% <75µm	%
Solwezi dolomite	104.3	32.2	19.3	72.5	80.4
Mkushi dolomite	103	30.5	19.1	71.5	77.1
Lilyvale Farm dolomite	106	30.7	21.1	97.2	84.2
Ndola Lime Ltd limestone	98.7	53.7	1.9	81.4	90.42

Table 2 Summary of unit operation costs for agricultural lime production

Unit operation	Cost per tonne (US\$)
Bush clearing & soil removal	0.20
Drilling & blasting	0.70
Loading & haulage	0.55
Manual crushing	10
Milling (and bagging)	20.10
Total production cost	31.55

Table 3 Response of crops to lime application at trial sites in Mkushi, Zambia

Agricultural lime treatment	Maize	Groundnuts
	(Grain yield kg/ha)	(Grain yield kg/ha)
Control (unlimed)	2490 - 5200	180
Lime (spot)	3050 - 5490	200 - 320
Lime (broadcast)	3570 - 6760	210 - 240
Double lime (spot)	3430 - 4880	150 - 200
Double (broadcast)	3110 - 5610	90 - 320

Table 4 Value Cost Ratio (VCR) scenarios for maize

Value Cost Ratio (VCR)				
Lime cost per tonne	High US\$60		Low US\$30	
Maize price per tonne	High US\$110	Low US\$50	High US\$110	Low US\$50
Extremely acid soil	9.1	4.2	18	8.3
Very acid soils	5.5	2.5	11	5
Acid soil	2.7	1.3	5.5	2.5