British Geological Survey

NATURAL ENVIRONMENT RESEARCH COUNCIL

DFID

Department For International Development

# FarmLime

## SUMMARY:

FarmLime (Low-cost lime for small-scale farming) is a multidisciplinary research project that aims to increase the food security of small-scale farmers by improving their access to agricultural lime. The basic concept was to locate suitable carbonate rocks in farming districts and produce agricultural lime using a low cost method, eliminating the high transportation costs that farmers currently incur if they use lime. The work was carried out in the small-scale farming districts of Solwezi and Mkushi in northern Zambia.

### Perceptions
The commonly held view is that small-scale farmers do not use agricultural lime because it is expensive, difficult to get hold of and they don't appreciate its benefits. A socio-economic survey carried out in Solwezi and Mkushi confirmed some of these views but indicated that farmers knew the benefits of using lime and that uptake of agricultural lime could be encouraged. The main constraints on the use of lime were the absence of soil testing and a lack of cash in the rural economy.

### Lime Resources
Carbonate rocks occur throughout Zambia including the farming districts with highly acidic soils. A technical evaluation programme found that the dolomite from Solwezi and Mkushi is suitable for the production of agricultural lime. It has a Neutralising Value (NV) of 103–104% Calcium Carbonate Equivalent (CCE) and a magnesium oxide (MgO) content of 19–21%. Dolomite suitable for agricultural lime (minimum 80% NV and 6% MgO) occurs in seven of the nine Zambian provinces.

### Lime Production
A low cost production method would be an ideal way to provide agricultural lime for small-scale farmers. Usually, agricultural lime is produced from dolomite by quarrying, crushing and milling. This could be carried out on a small-scale using manual extraction and crushing, and hammer milling. The cost of producing agricultural lime from the dolomite in Solwezi and Mkushi was estimated to be between US$20 to 31 per tonne. Following this research, entrepreneurs in Solwezi started small-scale production of agricultural lime.

### Crop Trials
The most effective means of showing the benefits of using agricultural lime was thought to be through demonstration crop trials. Maize and groundnut trials were set up in Mkushi. This area has highly acidic soils (pH 4.6 to 5) and low crop yields (e.g. 1.5 tonnes of maize per hectare). Limed plots produced up to 6.7 tonnes of maize and up to 320 kilogrammes of groundnuts per hectare. This convinced neighbouring farmers to use locally produced lime. The crop trials will run until 2005.

### Economics
The economic justification for using lime can be seen as the money earned through the sale of surplus crops. Where the price of maize is high and the cost of agricultural lime is low the economic benefits are very high. However, where the opposite is true the economic benefits are marginal although still in favour of using lime. However, even if there is a demonstrable economic benefit to the use of agricultural lime its use will still depend on the farmers having enough cash to buy it.

*Mkushi farming district, Zambia.*

*Small-scale miners, Zambia.*

*Lilyvale Farm lime plant, Zambia.*

# FarmLime
# Project Summary Report

Commissioned Report CR/03/066N

CJ Mitchell[1], S Simukanga[2], V Shitumbanuma[2], D Banda[2], B Walker[3], EJ Steadman[1], B Muibeya[4], M Mwanza[2], M Mtonga[2], & D Kapindula[4]

[1]BGS, [2]University of Zambia (UNZA), Lusaka, Zambia, [3]Consultant, Lincoln, UK [4]Geological Survey Department (GSD), Lusaka, Zambia

*This report is an output from a project funded by the UK Department for International Development (DFID) under the UK provision of technical assistance to developing countries. The views expressed are not necessarily those of the Department.*

**DFID Classification:**
Subsector: Geoscience
Theme: G1 Environmental mineral resource development
Project title: FarmLime: Low-cost lime for small-scale farming
Project reference: R7410

**Bibliographic reference:**
FarmLime Project Summary Report
CJ Mitchell, S Simukanga, V Shitumbanuma, D Banda, B Walker, EJ Steadman, B Muibeya, M Mwanza, M Mtonga, & D Kapindula
British Geological Survey Commissioned Report CR/03/066N
ISBN 0 85272 4624



## Foreword & Acknowledgements

This report summarises work funded by the Department for International Development Knowledge and Research programme, as part of the British Government's programme of aid to developing countries. The 'FarmLime: Low-cost lime for small-scale farming' project (R7410) set out to investigate a way of improving the agricultural performance of small-scale farms through the use of low-cost agricultural lime produced within the farming district using locally occurring dolomite. The main technical research phase (1999 to 2001) will be followed with a dissemination workshop phase (2002 to 2005).

FarmLime has been a multidisciplinary research project led by the British Geological Survey (Clive Mitchell, Ellie Steadman and Simon Inglethorpe). The field and technical work was largely conducted in Zambia by researchers from the University of Zambia (Stephen Simukanga, Victor Shitumbanuma, Diana Banda, Moffat Mwana & Mathew Mtonga), the Zambian Geological Survey Department (Boniface Muibeya & David Kapindula), consultant Briton Walker and the farmers of the Mkushi & Solwezi farming districts.

*Further information about the FarmLime project can be obtained from the Project Manager, Clive Mitchell at the British Geological Survey, Keyworth, Nottingham, NG12 5GG, UK, email:* cjmi@bgs.ac.uk

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

DFID Department for International Development

## INTRODUCTION:

# Farming fortunes

Farming is probably the most important occupation in southern Africa and provides livelihoods and food security for a large proportion of the rural population. However, the countries of southern Africa struggle to find the best way to encourage and promote the development of the small-scale farmer. These farmers have meagre resources and barely produce enough food for themselves and their families.

The main natural resource of a small-scale farmer is the land he farms. However, without the use of agricultural inputs such as fertiliser and lime, growing crops on the same patch of ground would, after a few years, exhaust the natural fertility of the soil and result in low crop yields. Small-scale farmers in southern Africa use a traditional shifting cultivation system, known as *chitemene,* to help maintain the condition of their soil. Land is farmed for several years and then left fallow for a generation. Vegetation in the fallow area is chopped down and burnt with the ash ploughed into the soil to provide nutrients for the new crops. In an attempt to meet the increasing demand for food, especially from urban centres, fallow land is being farmed many years before it has a chance to fully recover and fertilisers are more commonly used to improve the crop yields. This has created the problem of soil acidity, especially in the high rainfall areas of northern Zambia and as a result crop yields have declined.

The solution is to use agricultural lime which is defined as material containing 'the necessary qualities to neutralise acidic soils, provide essential nutrients to promote plant growth and correct magnesium deficiency' (ARC, 1996). Currently, few small-scale farmers use agricultural lime as it is either locally unavailable and/ or too expensive. If agricultural lime could be made locally available at an affordable price it would give small-scale farmers an opportunity to improve their crop yields. The findings of a previous DfID research project 'Local development of affordable lime in southern Africa' (R6492) concluded that agricultural lime could be produced on a small-scale from local dolomite within farming districts. The DfID research project 'FarmLime: Low cost lime for small-scale farming' was carried out to test these conclusions and the following sections of this report cover the project work:

- **Part One: Socio-economic survey,** a survey was carried out to find out what farmers knew about agricultural lime and whether uptake would be likely.
- **Part Two: Carbonate resource assessment,** the suitability of the available dolomite resources for production of agricultural lime was evaluated.
- **Part Three: Lime production research,** a small-scale production process involving manual extraction, crushing and mechanical milling was evaluated.
- **Part Four: Crop trials,** demonstrations using maize and groundnuts were carried out using agricultural lime produced as part of the project.
- **Part Five: Cost benefit analysis,** an analysis of the costs associated with the production and use of agricultural lime was carried out.

Photo opposite: *Dolomite outcrop, Solwezi, Zambia.*



*Solwezi farming district, Zambia.*

*Small-scale farmers, Zambia.*

*Mindeco lime plant, Zambia.*

**PART ONE:**

# Socio-economic survey

Zambia has up to 700 000 small-scale farms, which provide food for up to three million people. The current Zambian government has promised to improve 'the living standards of small-scale farmers and people at large through job creation, income generating activities and overall reduction in hunger and poverty' (Mengo, 2002). There are many Non-Governmental Organisations (NGOs) that support the small-scale farmer funded by international agencies such as USAid, Sida and World Vision.

The majority of Zambia's poorest people rely on small-scale farming for their livelihood and food security. Improving their crop yields through the use of agricultural lime would assist the farmers in producing enough food for their families and increase their income. A survey was carried out to find out what farmers knew about agricultural lime and to identify the means to encourage its uptake.

Previous research found that small-scale farmers do not use agricultural lime, as it is expensive to obtain, mainly due to the high transport costs from the few centralised production plants. Also, farmers do not have the cash to buy lime and if they did the lime was often not available. Some farmers were simply unaware of the need for agricultural lime. Other factors that contributed to this situation include the (mistaken) belief that fertiliser and agricultural lime are interchangeable, a lack of marketing by agricultural lime producers, a lack of information regarding its quality and use and its poor packaging/ labelling.



The current consumption of agricultural lime in Zambia is thought to be about 40 000 tonnes per year, most of which is supplied by five companies, namely Hi-Qwalime, Lilyvale Farm, Mindeco Small Mines, Uniturtle and Ndola Lime. These producers are keen to increase production but they are held back by the low demand and the high capital costs. The latent demand for agricultural lime is thought to be about 150 000 tonnes per year. This could only be realised if there was a dramatic increase in the use of agricultural lime by small-scale farmers.

The survey was carried out in Solwezi, North-Western Province and Mkushi, Central Province. The issues investigated included; awareness of crop production constraints, knowledge of the benefits of agricultural lime, accessibility and distribution of agricultural lime, affordability, and issues that facilitate/ constrain technology uptake. Both of the farming districts receive average annual rainfall greater than 1000 millimetre per year and have heavily leached soils with low pH.

A majority of the respondents indicated that they were aware of the poor soil conditions and would be willing to participate in crop trial demonstrations involving the promotion of agricultural lime.

*Zambian village.*

*Solwezi town, Zambia.*

*Zambian children.*

Great North Road, Zambia.


Farmers Union hoarding, Zambia.

Zambian children.

They expressed a willingness to involve Ministry of Agriculture, Food and Fisheries (MAFF) extension workers as they were seen as an effective communication channel and should be responsible for bringing agricultural lime closer to the farmers. It was proposed that agricultural lime could be procured in bulk by existing co-operatives set up for seed and fertiliser. Stockpiles could be kept at the MAFF district offices and extension workers should advise farmers on the application of agricultural lime. Also, it was suggested that 'farmer field schools' using the 'farmer to farmer' approach could be adopted for communicating the benefits of lime use.

**The main factors identified, which constrain the uptake of agricultural lime, are:**

**Accessibility and distribution of agricultural lime.** The few centralised producers in Zambia mainly supply the large-scale commercial farmers and are reluctant to supply the small volumes required by small-scale farmers.

**Lack of emphasis on agricultural lime use.** Farmers reported receiving very little advice on agricultural lime application from agricultural extension workers. This led to some farmers being unwilling to participate in the use of agricultural lime. There is a need to demonstrate the benefits of agricultural lime to small-scale farmers.

**Lack of soil sampling and testing facilities.** It was found that no soil testing is being carried out for the farmers in Mkushi and Solwezi district areas. Therefore, they do not know the pH of their soil and the amount of lime to apply. It was indicated that soil testing is expensive (US$9 per sample excluding transport) and time consuming.

It was found that most respondents were well aware of the benefits of agricultural lime despite having little or no practical experience of its use. This could be attributed to the practices of local commercial farmers who apply lime and produce up to ten tonnes per hectare of maize (compared to less than two tonnes per hectare for small-scale farmers). Previous crop trials using lime were found to be instrumental in raising awareness. However these trials are often short lived and unsustainable partly due to the difficulty in accessing lime.

Agricultural lime supply is geared to the large commercial farms and is usually supplied directly in bulk (current ex-works price of US$20 per tonne). Transport typically adds US$1 per tonne per ten km travelled. For farmers several hundred kilometres from the producer this multiplies the cost of lime several times and puts it beyond the reach of most small-scale farmers. Some producers are considering supplying the small volumes (50 kilogramme bags) required by small-scale farmers.

Many small-scale farmers were willing to be involved in a co-operative or farm group to produce agricultural lime from local dolomite resources. Such a co-operative venture would require significant investment and be expected to produce agricultural lime that matched the quality of the larger producers. Its success would hinge upon generating sufficient demand for agricultural lime and the ability of the small-scale farmers to pay for it. Acceptance of an alternative form of payment, such as bartering with maize, may be necessary but could not totally replace the need for cash payment.

Stimulating the demand for agricultural lime by small-scale farmers has been attempted by government and NGO food security programmes without much success. However, this is probably the key to unlocking the potential to increase the agricultural productivity of small-scale farming.

## PART TWO:

# Carbonate resource assessment

Most of the provinces in Zambia have carbonate resources however not all of these are suitable for the production of agricultural lime as they do not have the required technical properties. Many of these carbonates occur in the farming districts with acid soils, unfortunately there is often very little relationship between the natural soil pH and the underlying rock formations. For carbonate rocks to have any beneficial effect they have be extracted and applied on top of the soil.

The carbonate rocks limestone and dolomite are, respectively, composed of the minerals calcite ($CaCO_3$, calcium carbonate) and dolomite ($CaMg(CO_3)_2$, calcium magnesium carbonate). 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 capacity (i.e. a fixed weight of dolomite will neutralise more soil acidity than the same amount of limestone).

**The carbonate rocks currently worked commercially in Zambia include the:**

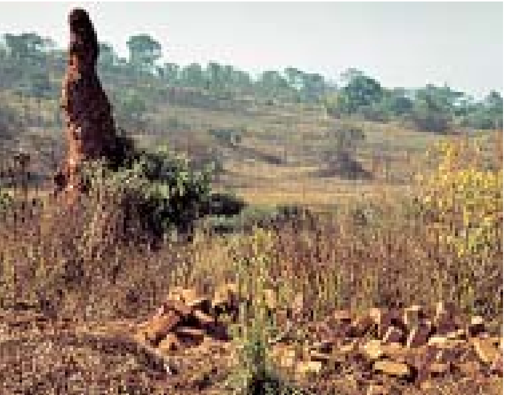
- Calcitic marbles of the Mampompo Limestone for aggregate, agricultural lime, cement and ground limestone mineral fillers (Lusaka, Lusaka Province);
- Calcitic marble of the Lower Kundelungu Formation for burnt & hydrated lime and cement (Ndola, Copperbelt province);
- Calcitic and dolomitic marbles of the Lower Kundelungu Formation for agricultural lime and stock feed (Kabwe & Mkushi, Central Province).



A technical evaluation programme was carried out, to determine the suitability of the dolomite resources in Mkushi and Solwezi for agricultural lime. The first stage involved fieldwork for reconnaissance and sampling; a total of 77 samples were collected from surface exposures and small pits. The Mkushi dolomite is an off white to grey, coarsely crystalline massive dolomitic marble with an estimated resource of approximately 6 million tonnes in the Munsakamba study area, to the north of Mkushi. The likely dolomite resource in Mkushi district is at least an order of magnitude greater. The Solwezi dolomite is an off white to grey, massive or finely laminated, friable dolomitic marble with an estimated resource of 43 million tonnes within the study area. The likely dolomite resource in the neighbouring area is upwards of at least 100 million tonnes.

Photo opposite: *Agricultural lime, Zambia.*

*Dolomite deposit, Mkushi, Zambia.*



*Sample collection, Solwezi, Zambia.*

*Laboratory test work, Zambia.*

**PART TWO:**

# Carbonate resource assessment

The second stage of the evaluation programme involved analytical testwork (using methodologies outlined in Mitchell *et al,* 1997) to determine their agricultural lime properties. These were 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 ($CaCO_3$) and/ or equivalent dolomite ($CaMg(CO_3)_2$). This is the key property in reducing soil acidity. In many countries, the neutralisation ability of agricultural lime is expressed in terms of the CCE. The CCE value for pure limestone is 100% and for pure dolomite 108%. Dolomite has a higher CCE value because dolomite has a lower molecular weight but the same neutralising power as calcium carbonate. 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). A key function of agricultural lime is to provide essential plant nutrients in the form of calcium and magnesium. An MgO content of 6% is considered to be a minimum for agricultural lime (Tether & Money, 1989). This eliminates limestones as they contain less than 2.2% MgO. It is commonly accepted that dolomitic agricultural lime is preferable and a dolomite with the minimum CCE of 80% would contain 17.5% MgO (a pure dolomite contains 21.9% MgO).



**Comparison with commercially available agricultural lime**

| Sample site | Neutralisation ability CCE wt % | Plant nutrient content | | Ease of pulverisation Grindability Wt% <75mm | Agronomic effectiveness Reactivity % |
|---|---|---|---|---|---|
| | | CaO Wt % | MgO Wt % | | |
| 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 |

*Dolomite deposit, Solwezi, Zambia.*

*Zambian village.*

*Sample collection, Solwezi, Zambia.*

*Hi-Qwalime quarry, Mkushi, Zambia.*


*Uniturtle lime plant, Lusaka, Zambia.*

*Mindeco lime plant, Lusaka, Zambia.*

| Potential for agricultural lime | Location |
|---|---|
| **Highest potential:**<br>CCE of 100% and greater + MgO content greater than 6% | **Dolomite**<br>Lilyvale Farm (Kabwe), Mkushi, Chombela and Lukunyi, Central Province, Solwezi, North-Western Province; Chingola, Copperbelt Province; Mvuvye, Eastern Province; Chivuna, Southern Province<br>**Calcitic dolomite**<br>Chilenje South, Lusaka Province, Mpongwe, Copperbelt Province |
| **Moderate potential:**<br>CCE between 80 & 100% + MgO content greater than 6% | **Dolomite**<br>Nkombwa Hill, Northern Province;<br>Chipata, Eastern Province;<br>Matanda, Luapula Province |
| **Lowest potential:**<br>CCE of less than 80% and/ or MgO content less than 6% | **Dolomite**<br>Mandanji, Central Province<br>**Dolomitic limestone**<br>Mandanji & Nampundwe, Central Province; Mvuvye, Eastern Province; Lusaka East, Lusaka West, Chilenje South & Kabwe Rd, Lusaka Province; Mpangala, Northern Province; Changushi, North-Western Province<br>**Limestone**<br>Solwezi, North-Western Province, Ndola Lime, Copperbelt Province; Lilyvale Farm (Kabwe) & Mpongwe, Central Province; Masangu, Southern Province; Mvuvye, Eastern Province |

**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. Generally dolomite is harder to grind than limestone.

**Agronomic effectiveness,** otherwise known as the reactivity, is a measure of the rate at which agricultural lime neutralises soil acidity. This gives an indication of how quickly agricultural lime will neutralise soil acidity. Generally, dolomite is slower to react with acid than calcite.

The dolomite samples from Mkushi and Solwezi compare favourably in their technical quality with commercially available agricultural lime from Lilyvale Farm and Ndola Lime *(see table opposite).* The carbonate resources of Zambia evaluated both in this, and the previous project, have been assessed for their suitability as magnesium-rich agricultural lime. The assessment was carried out by application of the following ranking based on neutralisation ability and plant nutrient content *(see table above).*

| | |
|---|---|
| High potential | 100% CCE or higher, plus an MgO content greater than 6%. |
| Moderate potential | 80 and 100% CCE, plus an MgO content greater than 6%. |
| Low potential | 80% CCE or lower and/ or an MgO content less than 6%. |

## PART THREE:

# Lime production

The production of agricultural lime is a relatively simple process which involves the extraction (quarrying and/ or mining) of carbonate rock and the processes of crushing and milling the rock to a powder. Often agricultural lime will be produced as a co-product alongside aggregate, burnt lime, cement and/ or mineral fillers. Research was carried out during the FarmLime project to determine if the methods of large-scale agricultural lime operations can be replicated on a small-scale, using appropriate technology and manual labour where appropriate.

Hard rock deposits use drilling and blasting to extract carbonate from opencast quarries; where softer rock is present a 'ripper' on the back of an excavator can be used to literally gouge the rock out of the ground. The primary crushing stage reduces the rock in size using a jaw crusher or impact mill followed by screening to remove the coarse material (which is recirculated to the crusher). The secondary milling stage uses an impact or hammer mill to produce a powder, which is classified to separate the remaining coarse material (which is recirculated to the mill) from the fine-grained product which can be sold as agricultural lime. This has a particle-size distribution with typically 100% finer than two millimetres, 60% finer than 400 microns and up to 50% finer than 150 microns.

The small-scale production research was based on the Munsakamba dolomite in Mkushi, with a theoretical consideration of the best extraction methods and practical trials using a Zambian built hammer mill. Geotechnical testing, including determination of the compressive and tensile strength, characterised the dolomite as medium hard to hard, confirming the need for drilling and blasting to extract the rock from the ground.



Manual bush clearing and loose soil removal could be carried out using a small work force at a cost of US$0.20 per tonne of rock extracted. A portable petrol-powered hammer drill could be used to drill blast holes using a staggered-square drill pattern and blasting with 'Waterproof Dynamite' (60% Nitroglycerine) high explosive using Nitroglycerine-based 'Cordtex Detonating Fuse' for initiation. The cost of drilling and blasting is estimated to be US$0.70 per tonne of rock removed. Manual loading and hauling of the extracted dolomite using wheelbarrows is estimated to cost US$0.55 per tonne of rock hauled to the on-site processing plant. The overall estimated cost is US$1.45 per tonne of rock extracted.

Crushing of the dolomite to produce material of an appropriate size for the milling stage was carried out manually using sledgehammers. It was found that each man could crush approximately 100 kilogrammes per day of the harder Mkushi dolomite and up to 144 kilogrammes per day of the softer Solwezi dolomite. This was found to be the most expensive element of the production process as it was slow and labour

*Small-scale miners, Zambia.*

*Aggregate production, Zambia.*

*Dolomite crushing, Mkushi, Zambia.*

*Dolomite quarrying, Mkushi, Zambia.*

*TD hammer mill.*

*Agricultural lime.*

**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 |



intensive, costing US$10 per tonne for the Mkushi dolomite (and US$7 per tonne for the Solwezi dolomite). 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 which was originally designed for maize milling and was modified for milling of dolomite. The modified mill underwent rigorous milling trials in the laboratory and the field to determine its performance. 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 (three millimetre diameter apertures). The aim of the trials was to produce ground material that matched the fineness of commercial agricultural lime.

Field trials using the Mkushi dolomite produced ground material with 100% finer than two millimetres, up to 87% finer than 425 microns and up to 70% finer than 150 microns. The production capacity of the mill was on average 500 kilogrammes per hour. Similar trials in Solwezi (using the much softer dolomite) had an average feed capacity of 560 kilogrammes per hour and produced lime with 99% finer than 425 microns and 77% finer than 150 microns. 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 *(see table above)*. The overall cost is US$31.55 per tonne (US$1.58 per 50 kilogrammes); this could be reduced to US$28.5 (US$1.43 per 50 kilogrammes) per tonne if the softer Solwezi dolomite were worked. Use of a manual jaw crusher could reduce the production costs down to US$20 to 25 per tonne. It is estimated that capital and start-up costs would be in the region of US$5000 (2002 prices).

The research has led to the 'spontaneous uptake' of agricultural lime production by local entrepreneurs in Solwezi following the field trials of the modified TD Hammer Mill. Agricultural lime is now being made on a small-scale for sale to local farmers in 50 kilogramme bags (and smaller) for US$1.4. To this date (August 2002) over five tonnes of agricultural lime has been produced and sold.

**PART FOUR:**

# Crop trials

Small-scale farmers are well aware of the benefits of using fertiliser to improve their crop yields and are prepared to use it when it is available. However, despite their apparent awareness of the benefits of using agricultural lime they do not have the same degree of willingness to use it even if it is readily available. The problem is precisely that lack of use; why should farmers use agricultural lime if it remains outside the experience of themselves and their neighbouring farmers?

Therefore, an important element of the FarmLime project was demonstration crop trials to show farmers the benefits of using agricultural lime. Mkushi district was chosen as it has acid soils in an area with carbonate resources suitable for agricultural lime production (and an active agricultural lime producer, Hi-Qwalime). The milling trials carried out using the modified TD Hammer Mill provided the agricultural lime for the project demonstration crop trials.

The sites chosen for the demonstration trials were Chalata and Kasansama agricultural camps, both being accessible to small-scale farmers, with acid soils and with farmers willing to participate in the work. The farms all had pale-coloured heavily leached sandy soils with pHs in the range from 4.6 to 4.9 and exchangeable aluminium contents of 0.11 to 0.24 milli-equivalents ($Al3^{+}$ & $H^{+}$) per hundred grams of soil. Further analysis showed the soils to have very low nitrogen contents, low to moderate amounts of available phosphorus, low amounts of potassium and only trace amounts of boron. The amount of agricultural lime required for the demonstration sites was based on the exchangeable aluminium content of the soil and the effective neutralising value of the agricultural lime to be used. This was determined to be 450 kilogrammes per hectare for Chalata and 200 kilogrammes per hectare for Kasansama.



Each of the demonstration sites were divided into ten plots — five for maize and five for groundnuts. The plots were prepared as follows: a control plot with no lime, two plots with the calculated lime application rate and two with double the lime application rate. The agricultural lime was added as either a 'spot application' (i.e. applied to the immediate vicinity of the plant only, following the ideals of conservation farming) or 'broadcast application' (i.e. spread over the entire plot). Fertiliser (Compound D) was applied to the maize plots only.


*Bagged agricultural lime.*


*Groundnut plants, Mkushi, Zambia.*


*Groundnuts (peanuts).*

*Maize crop, Mkushi, Zambia.*

*Maize cob.*

*Groundnut inspection, Mkushi, Zambia.*

**Grain yield response of maize and groundnuts to different lime applicaton rates and methods at crop trial sites in Mkushi, Zambia**

| Agricultrual lime treatment | Maize (Grain yield kg/ha) | Groundnuts (Grain yield kg/ha) |
|---|---|---|
| Chalata | | |
| Control (unlimed) | 2489 - 4414 | 179 - 183 |
| 450 kg/ ha (spot) | 3053 - 4747 | 259 - 320 |
| 450 kg/ ha (broadcast) | 3567 - 4107 | 242 - 244 |
| 900 kg/ ha (spot) | 3426 - 4883 | 154 - 208 |
| 900 kg/ ha (broadcast) | 3110 - 4490 | 88 - 149 |
| Kasansama | | |
| Control (unlimed) | 5203 | 183 |
| 200 kg/ ha (spot) | 5490 | 201 |
| 200 kg/ ha (broadcast) | 6764 | 210 |
| 400 kg/ ha (spot) | 4787 | 182 |
| 400 kg/ ha (broadcast) | 5613 | 320 |



The crops were planted according to the MAFF 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 are harvested in May of each year and data on grain weight are gathered to determine any change in yield attributable to liming.

The findings of the most recent harvest (2001–2002) are shown in the table above. The maize and groundnuts from the limed plots generally gave higher yields than the unlimed plots.

The greatest achievement of the agricultural lime demonstration is the uptake of agricultural lime by the farmers neighbouring the trial sites. This has been helped by the availability of agricultural lime (produced by Hi-Qwalime) through the Mkushi Agricultural Company (MAC) for US$1 per 50 kilogramme bag.

**PART FIVE:**

# Cost benefit analysis

The benefits of using locally produced 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. The wider benefits will include improved food security, poverty alleviation through increased employment, improvement of the farming environment and, ultimately, a decrease in food imports (and an increase in export opportunities). However, this all hinges on creating a demand, and the ability of small-scale farmers to pay, for agricultural lime. A cost benefit analysis was carried out in the project 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:

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

The UN Food & Agriculture Organisation (FAO) believe that for small scale farmers a VCR above two 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). In Zambia the VCR required for uptake of agricultural lime is likely to be much higher due to the uncertainties of the weather, input and output marketing, availability and price, the variation in harvested crop prices and the shortage of cash in the rural economy.



The response of crops to the addition of agricultural lime varies according to many factors including the amount of lime added, its neutralising value, the soil type and the type of crops grown. 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 used by the following amounts (depending on the acidity of their soil):

| | |
|---|---|
| **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 ten kilometres the lime has to be transported (this can multiply the cost several fold for remote farmers).


*Crop trial plots, Mkushi, Zambia.*


*Maize cobs drying.*


*Zambian children.*

*TD hammer drill.*

*Milling dolomite.*

*Hammer mill screen.*

**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 |



In the value cost ratio calculations the different maize responses and lime application rates given for the different soil acidity, two maize values (US$50 and US$110 per tonne) and two agricultural lime costs (US$30 and US$60 per tonne) were used. The table above gives the range of VCRs and it can be seen that the use of agricultural lime is economically beneficial in most cases. The results show that small-scale 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. However, those farmers living a long distance from the source of their inputs, farm moderately acid soils and can only realise a low price for their maize will have greater costs and a smaller increase in their income.

Several methods have been used to estimate the potential usage of agricultural lime in Zambia. The amount of agricultural lime required for neutralisation of naturally occurring soil acidity and the acidity introduced by the use of fertilisers is estimated to be approximately five million tonnes. Assuming that one tonne of agricultural lime is required to counteract the acidity introduced by one tonne of fertiliser this puts the potential demand at 60 000 tonnes per year for small-scale farmers. A more realistic prediction of lime usage by small-scale farmers by 2005 is 10 000 tonnes per year.

Small-scale agricultural lime production is only likely to be successful where the costs are kept low, the production methods are simple and the lime is sold to local farmers for cash. The most likely areas for successful small-scale lime production operations are those areas with very acid soils that are remote from the existing producers and have a source of dolomite that is easy to extract. Two production scenarios were considered — the first, small-scale (400 tonnes per year) and the second slightly larger (1200 tonnes per year). The first scenario, employing manual extraction and crushing (using a jaw crusher) and milling (using a hammer mill), is estimated to cost about US$20 per tonne and the second, which is similar except that extraction is by drilling and blasting, is estimated to cost US$33 per tonne.

There are significant economic benefits in the use of locally produced agricultural lime in Zambia. If half of the small-scale farmers used agricultural lime this would increase maize production by 750 000 tonnes per year and reduce the huge amount of money currently spent on importing maize. Creation of local small-scale lime production operations would not only provide the necessary lime but also provide employment and inject cash into the rural economy.

# CONCLUSION:

## Socio-economic survey

Small-scale farmers are aware of the benefits of using agricultural lime but 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 the lime demand for their farm. Bartering may be the solution for farmers that cannot pay cash for lime. Farmers are willing to participate in co-operatives or farm groups set up to produce agricultural lime on a small-scale.

## Carbonate resource assessment

There are ample resources of dolomite rock available throughout Zambia for agricultural lime production. The Neutralising Value (NV) is the most important property to determine and should be greater than 80% Calcium Carbonate Equivalent (CCE). The magnesium oxide (MgO) content should be greater than 6%. Dolomitic rock that meets these requirements has been shown to occur in seven of the nine Zambian provinces.

## Lime production research

Extraction of the dolomite in Mkushi would require drilling and blasting. Manual crushing of the rock to less than ten millimetres is a relatively slow and expensive process. A manual jaw crusher would be a faster and cheaper alternative. The modified TD Hammer mill is capable of producing up to 1200 kilogrammes of agricultural lime per day with the required particle size (100% < two millimetres, 60% < 400 millimetres and up to 50% <150 millimetres). The production cost was found to be relatively high at US$31 per tonne for the Mkushi dolomite; this would probably be lower (US$29 per tonne) for the softer dolomite in Solwezi. Use of a manual jaw crusher could reduce the cost to US$20–25 per tonne.



## Crop trials

Demonstration plots (maize and groundnuts) were established in Mkushi in an attempt to convince local small-scale farmers of the benefits of using agricultural lime. The soil in these plots is highly acidic and had a lime demand of 200 to 450 kilogrammes per hectare. The highest yields achieved were 6.7 tonnes of maize and 320 kilogrammes of groundnuts per hectare, which compared to the lowest control plot (unlimed) yields of 2.5 tonnes maize and 48 kilogrammes groundnuts. Farmers neighbouring the demonstration sites have started to use agricultural lime available locally at US$1 per 50 kilogramme bag.

## Cost Benefit Analysis

The economic benefits to the small-scale farmer can be calculated from the value of the extra maize grown compared to the cost of the lime used. The demand for agricultural lime by small-scale farmers by 2005 is estimated to be approximately 10 000 tonnes per year. The estimated cost of producing agricultural lime on a small- and a medium-scale was US$20 and US$33 per tonne respectively. Although there is a demonstrable economic benefit to the use of agricultural lime its use will ultimately depend on the small-scale farmer having enough cash to purchase it.

*Small-scale farmers, Zambia.*

*Zambian restaurant, Solwezi, Zambia.*


*Maize crop, Mkushi, Zambia.*

## Recommendations:

1. A simple and cheap test should be developed and made available for small-scale farmers to test their soils to determine agricultural lime demand. It is recommended that UNZA is commissioned to devise a reliable test.

2. Agricultural lime should be made available to all small-scale farmers. It is recommended that for farmers who cannot afford to buy lime an alternative form of payment should be devised, such as bartering.

3. Information on the quality of the carbonate resources that are suitable for agricultural lime should be made widely available. It is recommended that the GSD be commissioned to produce an annotated resource map of Zambia and ensure that it is disseminated to all stakeholders.

4. Small-scale lime production facilities should be established in those small-scale farming districts that have acid soils and poor access to agricultural lime. It is recommended that the FarmLime production methodology be used for these facilities, using manual extraction, a manual jaw crusher and a hammer mill. A good starting point for this would be to encourage existing small-scale producers, such as those in Solwezi.

5. The key to uptake is education and continued demonstration of the benefits of using agricultural lime. Demonstration of the benefits of using agricultural lime should be carried out in all small-scale farming districts to encourage the use of agricultural lime. It is recommended that UNZA be commissioned to establish crop trial demonstrations (using maize and groundnuts) such as those carried out by the FarmLime project.

## References:

ARC Southern (1996) Arclime — Agricultural Magnesian Limestone. Special products factsheet SP6.

Mengo, V (2002) Kapiri woman sees hope in Heifer Project International. *Zambia Daily Mail* (newspaper), Monday, March 11, 2002, p. 7.

Mitchell, CJ, Inglethorpe, SDJ, Tawodzera, P, Bradwell, S & Evans, EJ (1997) Local development of affordable lime in southern Africa. *British Geological Survey Technical Report.* WC/97/20. pp 120.

Tether, J & Money, NJ (1989) A review of agricultural minerals in Zambia. *Proceedings of the East and Southeast African Geology Workshop on Fertiliser Minerals,* Lusaka Dec 8–10, 1987.

**Economic Minerals and Geochemical Baseline Programme**

**British Geological Survey,
Keyworth, Nottingham NG12 5GG
United Kingdom**

**Tel: +44 1159 363494
Fax: +44 1159 363520
Email: minerals@bgs.ac.uk
www.mineralsUK.com
www.bgs.ac.uk**