FINAL REPORT

PHASE I

PHOSPHATE FERTILIZER AND AGRICULTURAL LIMESTONE PRODUCTION AND DISTRIBUTION FEASIBILITY STUDY IN UGANDA

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OF
PHOSPHATE FERTILIZER AND AGRICULTURAL LIMESTONE PRODUCTION AND DISTRIBUTION IN UGANDA

I. Phosphorus Fertilizer Production Potential in Uganda

Background:

Phosphate Rock is the only naturally occurring ore that is used in making commercial phosphate fertilizers throughout the world. Uganda has a large deposit called Sukulu Hills Rock which is located near Tororo. It is estimated that this deposit contains over 200 million tons reserve of which 130 million tons is high enough grade (% phosphorus) to be economically mined and processed into various phosphate fertilizers. This phosphate rock when mined and beneficiated (concentrated through physical and chemical processes) is among the highest phosphate content (38-41%) rocks in the world. This large natural resource could supply fertilizer phosphorus needs of Uganda (100%), Kenya (37%), Tanzania (11%) and lesser amounts to other countries in the PTA for nearly 200 years.

In 1962 construction of a phosphate fertilizer plant was begun near Tororo and Simple Superphosphate was commercially produced until the early 1970's. Since then no phosphate fertilizers have been manufactured in Uganda.

Need for Phosphorus Fertilizer in Uganda:

Virtually all agronomically important soils in Uganda need phosphorus to substantially increase crop yields. Research has shown that it is not uncommon to get yield increases in excess of 50% if adequate amounts of phosphorus are applied. This is also true for most other countries in East Africa.

Potential Uses of Uganda's Phosphate Rock Deposits:

There is considerable interest in using finely ground phosphate rock or partially acidulated phosphate rock (PAPR) (adding enough acid to only acidulate a portion of the phosphate rock) for direct application to farmers fields in Uganda, as they are considerably cheaper than other phosphate fertilizers. For these two products to be used effectively two criteria are necessary: 1) the soils must be quite acid, and 2) the phosphate rock must be at least of medium reactivity (a relatively high % of the phosphate rock must be available to the plant). Neither of these criteria are likely to be met, since most all of Uganda's soils, except for the drained swamplands, are only slightly acidic in nature (which is fortunate) and the phosphate rock on chemical analysis proved to be very unreactive and most likely unsuitable for <u>direct application</u>.

On the otherhand the Ugandan phosphate rock has some ideal characteristics for its manufacture into either Simple Superphosphate (SSP) (treated with sulfuric acid) and Triple Superphosphate (TSP) (treated with phosphoric acid). The Ugandan phosphate rock is a fine granular material in nature so little if any crushing would be needed in processing and the deposit is very high in phosphate content so high grade fertilizer can be produced rather easily. The SSP would be 21% phosphate and the TSP would be about 46%.

Agronomic Studies Needed:

The Makerere University/FAF and the Ministry of Agriculture with the USAID/MFAD Project cooperating will field test all phosphate fertilizers that the Tororo plant is anticipating manufacturing. This research will be conducted starting in the second rains of 1988 and continue through 1989 and beyond.

It is hoped that solid recommendations as to amounts and types of fertilizers that should be produced can be made. Direct application of phosphate rock and PAPR will also be included in the research to verify in the field if there are any agronomic benefits. The International Fertilizer Development Center (IFDC) has agreed to make all of the fertilizer materials for these experimental trials from the Sukulu Hills deposit. TICAF is very enthusiastic that this work be carried out to help them in their plans for the manufacture of appropriate fertilizers for Uganda and other East African countries.

Economic Projections of Phosphate Fertilizer Production:

Mr. Tinaako, Project Manager of TICAF, indicated the World Bank feasibility study showed that the Tororo Phosphate Plant would be economically viable on an annual production of 250,000 metric tons per year of SSP or equivalent of other products. The initial cost of the plant would be about 100 million US$ and cost per metric ton of SSP would be about $200 which would be quite competitive on the world market and certainly there would be a comparative advantage to supply E. Africa because of lower transportation costs. The plant is projected to have an economic internal rate of return of about 15% and a financial return on equity investment of 27-28%. By the sixth year of production at equivalent production of 250,000 metric tons per year of SSP, net receipts are estimated at US$ 15-18 million per year.

II. Agricultural Limestone Needs and Production Potential

Background:

Present information indicates that two deposits of limestone are known in Uganda: one near Tororo and one near Kasese in western Uganda. In the 1950's about 75,000 long tons of agricultural limestone was produced from these two sites. Since that time it does not appear that any has been produced.

In recent years many swamplands in Uganda (especially in SW Uganda) have been drained for vegetable crop production. Initially these soils were very productive but many of these soils have now gone out of production due to their extreme acid formation. In their natural state these soils contain large quantities of reduced forms of sulfur - when they are drained, with time the sulfur turns to sulfuric acid and renders the soils unproductive. Adding agricultural limestone is the only way to counteract this acidity and return these soils to their formerly productive state.

Production:

The production of agricultural limestone is a relatively simple process of quarrying, crushing and sieving to the fineness needed. Characteristics of the limestone deposits must be known to estimate the cost of production and equipment needed. In general a limestone production plant should cost about 1.0-1.5 million US$. IFDC has taken samples of the limestone deposits and will determine all the physical characteristics as well as its quality for agricultural uses.

Research Needed:

Once the quality of the limestone is determined it will be necessary for the Ministry of Agriculture with USAID/MFAD Project cooperating to run field tests to determine the amount of limestone needed to return the drained soils to a productive state. The number of hectares needing limestone must be determined so production needs are known.

I. Background/Objectives

IFDC responded positively to a request from USAID/Uganda by telex dated March 28, 1988 to provide a short-term (2 weeks) consulting engineer to conduct a pre-feasibility study for "phosphate fertilizer and agricultural limestone production and distribution in Uganda". This is one of the recommendations in the "New Project Implementation Plans" prepared under the Uganda Food Production Support Project, March 1988. This report was prepared by Dr. Richard R. Newberg, Agricultural Cooperative Development International, 50 F Street, N.W., Suite 900, Washington, D.C. 2001, USA.

The study dealt mainly with an agreement between the Government of Uganda (GOU) and US Agency for International Development (USAID) for support of cooperatives and agribusiness development referred to as "Implementation of the Cooperative Agriculture and Agribusiness Support Project (CAAS) involving Uganda Cooperative Alliance (UCA), Ministry of Cooperatives and Marketing (MCM), and Uganda Central Union Ltd. (UCCU).

The purpose of this report is to address chapter VII of the above study relating to the fertilizer/limestone feasibility study. The above consultant recommended that the study be conducted in two phases: (1) as soon as possible an initial reconnaisance level survey should be carried out and (2) a second phase would involve implementation of the feasibility study but including modifications as suggested in Phase I. Phase I was to make an initial assessment of feasibility of using phosphate and limestone ores as agricultural inputs. It would also include a more precise statement of work and inputs required for the feasibility study. Phase I would emphasize the potential for partially acidulated phosphate rock, but would involve potentially other more sophisticated products such as DAP, MAP and NPK.

The objectives are: (1) to carry out a full technical and economic feasibility level study of a) the development of local production of rock phosphate and acidulated rock phosphate production based on rock phosphate deposits in the Tororo area and b) the development of agricultural limestone production at one or more locations and (2) to carry out a pre-feasibility level analysis of more advanced phosphate products based on phosphate deposits in the Tororo area such as SSP and TSP; DAP, MAP and NPK products appear unlikely but should also be examined. The consultants report above provided a summary of:

1. Agriculture in the Economy
2. Land Resource Base and Utilization
3. Farming Systems and Cropping Patterns
4. Essentials for Development and Modernization of Agriculture
5. Fertilizer Requirements
6. Past Fertilizer Consumption and Use
7. Crop Yields

The IFDC engineering consultant spent two weeks (April 25-May 6) in Uganda to address Phase I, initial reconnaisance level study.

II. Tororo Phosphate Reserves/Historical Production

Historical

Some limited information is published on the Tororo phosphate deposit and the production scheme that was used during the period (early 60's to early 70's). The deposit known as Sukulu Hills, near the town of Tororo, was discovered in 1939 during a Geological Survey of Uganda. In 1953 Monsanto Co., Frobisher Ltd., and Uganda Development Corporation (UDC) formed the Tororo Exploration Co., (TEC) and carried out a full survey of the total of 202 million tons in the three valleys. Of this, 130 million tons was estimated as having an average grade of

13.1% P_2O_5 and 0.2% Nb_2O_5.

The ore (run-of-mine) is charaterized by unusual features: (1) igneous type having a low level of solubility in neutral ammonium citrate indicating a very low potential for use as a direct application fertilizer (without some chemical treatment). IFDC measurement of solubility of a concentrate containing 37.9% P_2O_5 obtained after beneficiation indicated only 1.5% P_2O_5 soluble in neutral ammonium citrate, 2.7% P_2O_5 soluble in 2% citric acid and 4.8% soluble in formic acid. The concentrate would be the product used for direct application or for chemical processing (2) run-of-Mine ore (before beneficiation) contains a high content of iron (about 29% as Fe_2O_3) and aluminum (about 11% as Al_2O_3) which can be removed by a complicated beneficiation scheme (3) run-of-mine ore is small in particle size in its natural state and does not require crushing as many other igneous types do (4) the beneficiation scheme used in the original plant provided an extremely high-grade, high-quality concentrate containing 40.5-41.5% P_2O_5 and 0.7-1.2% Fe_2O_3 indicating a very high percentage of fluoroapatite, 3 Ca_3 (PO_4) 2 CaF_2. For comparison, Kola is 38-39% P_2O_5, Taiba is 37-38%, Togo is 37% and Phalaborwa is 35-37%.

Studies conducted initially (1950's) were to export the high-grade concentrate but transport costs proved to be a major obstacle - approximately 1000 km to a seaport. One study was based on production of 400,000 ton per year (tpy) of concentrate equivalent to 164,000 tpy of P_2O_5 (concentrate contained 41% P_2O_5).

Instead of producing a concentrate for export it was decided to establish a much smaller scale plant to make single super-phosphate (SSP) at 25,000 tpy equivalent to about 5,000 tpy P_2O_5. In December 1955, Tororo Industrial Chemicals and Fertilizer Ltd. (TICAF) was incorporated with Uganda Development Corporation (UDC) as the major shareholder. Construction was begun around

1962 on a site on the north side of the road leading from Tororo to Jinja which is served by the main rail line from Mombasa, Kenya to Kampala, Uganda.

During operation until the early 70's the complex consisted of phosphate mining/beneficiation, sulfuric acid production based on imported solid sulfur and a single superphosphate (SSP) granulation plant. The SSP product contained about 21% P_2O_5 in water-soluble form.

A brief description of the plant is given in Phosphorus and Potassium No. 27, January/February 1967, pages 14-15.

At this time no phosphate fertilizers are being produced in Uganda.

Recent Studies

In early 1980 the Bearden-Potter Corporation was commissioned by TICAF through a World Bank loan to make an indepth study to reopen the mine and beneficiation plant and to compare several fertilizer production alternatives, including SSP, TSP, DAP, MAP and PAPR. It is understood that the study was conducted in stages I and II, although this study has not been available to the IFDC consultant. Apparently the product selected was 4-18-0 ammoniated superphosphate (SSP type) in granulated form consisting of a mixture of SSP and CAN. Economic and financial analysis results are not known. The plant envisioned would export to Kenya, Tanzania, Sudan, Ethiopia, Rwanda and Burundi and local needs of Uganda, with about 85% of output going to Kenya and Uganda. This study is based on a capacity of 50,000 tpy P_2O_5 or about 10 times the capacity of the original plant.

It is understood that the original study will be updated (to include TSP as well as SSP) with funding from African Development Bank (ADB) to the GOU programmed for 1989. Presumably the plant would be based on export to other countries (ref. telex to USAID/Uganda and letter to AID from Mr. Tinaako, TICAF Project Manager, 26 April, 1988).

III. Phosphate Alternatives for Uganda

The primary interest of USAID in sponsoring the IFDC consultancy is to develop a technical and cost effective scheme to use the Tororo phosphate to meet current and projected P_2O_5 needs of Uganda. In a prior consultancy involving an IFDC agriculturalist a work plan was provided for USAID funding to evaluate Tororo phosphate in Uganda. The project focused on a comparison of SSP and partially acidulated phosphate rock (PAPR). The recommended country program in Uganda is patterned after regional programs IFDC has conducted for about 10 years in Latin America and 4 years in West Africa. The programs are based on use of finely ground local rocks for direct application where agronomically acceptable; if not cost-effective modified products using these rocks not suitable for direct application are evaluated such as PAPR-type products. Potential alternative products which may be considered are:

1. Ground phosphate rock (PR) with no acidulation for direct application - rocks may be low, medium or high reactivity.
2. Sulfuric acid-based partially acidulated phosphate rock (SAB-PAPR) - uses only 25% or 50% of sulfuric acid required to make SSP and may be run-of-pile (ROP) or granular form with ROP form lower cost.
3. SSP - fully acidulated with 100% of sulfuric acid and may be ROP or granular as in item 2.

These are the main products of potential interest to Uganda at present. Other products could be based on use of phosphoric acid, mixture of sulfuric and phosphoric acids or nitric acid. These products might be combined with other nutrients or organic waste-type materials.

IFDC experience and agronomic results to date are based mainly on use of sedimentary (medium to high reactivity) rocks in Latin America and West Africa. A new program is emerging with financial support of UNDP/World Bank to evaluate phosphate and other agro-minerals in East and Southeast Africa. In general agronomic effectiveness is about 90% of fully acidulated SSP in acid tropical soils of Latin America and West Africa, when SAB-PAPR at 50% acidulation is used. Cost effectiveness is dependent upon the specific economic situation.

Unfortunately, agronomic data from IFDC and other researchers is very sparse for use of igneous rocks for direct application or as modified products made there from such as SAB-PAPR. Igneous rocks generally have a very low to low solubility (reactivity) and low surface area and are not recommended for direct application even on acid soils - Sukulu Hills (Uganda) rock falls in this category. When any rock, sedimentary or igneous, is partially or fully acidulated there is a water-soluble P_2O_5 and neutral ammonium citrate soluble P_2O_5 which is termed "available" P_2O_5. The so-called non-available P_2O_5 may become slowly available in acid soils providing residual P_2O_5 for subsequent crops, depending on the solubility (reactivity) of the original rock. This assumption seems to hold true for sedimentary rocks, but is questionable for igneous rocks.

Thus more research is needed to establish the relative agronomic effectiveness of PAPR derived from igneous rocks such as in Uganda.

IFDC's goal in phosphate research may be summarized as follows:

1. Assist developing countries to utilize indigenous resources.
2. Use ground PR directly where both agronomically and economically acceptable (normally the cheapest form of P fertilizer).
3. Use SAB-PAPR to reduce sulfuric acid consumption and

reduce cost compared with SSP (fully acidulated).

4. Use rocks not suitable for SSP due to impurities (iron and aluminum).
5. Use PAPR-type products in close proximity to production site (not for export).
7. Use run-of-pile (semi-granular) form in lieu of granular form to reduce cost.
8. Mix PAPR-type products with other ingredients to make NP or NPK products.
9. Convert existing SSP plants to PAPR with minimum additional investment.
10. Ship higher grade P_2O_5 product as PAPR compared with SSP.
11. Reduce foreign exchange requirements such as for imported sulfur or sulfuric acid by reducing S consumption.
12. Supply adequate sulfur nutrient in the PAPR.
13. Generate a local source of employment.
14. Make P fertilizer available on a timely basis.
15. Try to make P fertilizer more affordable for the small farmer in developing countries.

Many of the above goals have been met in Latin America and West Africa and in some cases commercial production and use have been achieved; in other cases production schemes are under consideration. The state of knowledge on rock phosphate in West Africa has been summarized recently by R. Binsack of GTZ, West Germany.

IV. Research Program in Uganda

IFDC is organizing a research program in Uganda to evaluate several forms of phosphate derived from Sukulu Hills phosphate.

A. Cooperation with TICAF

TICAF, with approval from UDC, has entered into an agreement with IFDC for cooperative research in several areas. The first activity ongoing is to supply up to 5 tons of Sukulu Hills concentrate for processing by IFDC in Alabama on an as-needed basis. Products will be returned to Uganda for agronomic trials (see below). TICAF will assist in developing less complex beneficiation schemes for Tororo phosphate, including use of local flotation reagents. TICAF desires to establish a research capability requiring outside funding and IFDC has agreed to assist in seeking funds for TICAF. A detailed workplan has been submitted to IFDC (contingent on funding). A memorandum of understanding (MOU) between TICAF and IFDC has been signed.

On April 29 a meeting was held with Mr. F. Tinaaka and Mr. J. B. Sempa of TICAF with Mr. Owen W. Livingston and Mr. Isaac Aluba. The MOU was discussed indicating IFDC will support TICAF at $2000 per year and will seek donors for other funds needed for the work plan.

The source of the Sukulu concentrate being sent to IFDC was also discussed. It is some of the original material from the old plant. According to Mr. Sempa it was sweepings and should have 40% P_2O_5 and about 1% Fe_2O_3. The equipment cannot be used to produce any new concentrate. Mr. Sempa believes he has about 5 tons recovered which could be made available to IFDC.

It is now confirmed that TICAF has no functioning equipment with which to prepare new Sukulu Hills phosphate concentrate. If this becomes a bottleneck in the future new concentrate must be prepared outside of Uganda.

B. Cooperation with Makerere University

IFDC and the Faculty of Agriculture, Soil Science Department, of Makerere University are cooperating with Prof. J.Y.K. Zake and coworkers to agronomically evaluate the Sukulu Hills experimental P products which may be made by IFDC and/or TICAF. Other nutrients and additives may be tested along with P in these products. A workplan has been submitted by Dr. Zake and he is awaiting experimental products to begin trials. A MOU with the University is signed.

On April 28, 1988 a meeting was held at Makerere University to discuss the phosphate feasibility project with concerned officials. Those present were Dean Dr. John Mugerwa, Dr. William Fenster, Dr. Trevor Arscott, Dr. J.Y.K. Zake, Mr. Ken Lyvers, Mr. F.R. Tinaako, Mr. Isaac Aluba and the IFDC consultant.

There was some confusion regarding the previous assignment recommended by Dr. Richard Newberg in relation to the IFDC assignment. AID had some erroneous impressions concerning the feasibility study conducted by Bearden-Potter for World Bank on behalf of Tororo Chemicals and Fertilizers Company Ltd. (TICAF). This was cleared up in this discussion.

In the meeting it was agreed that TICAF make available Sukulu concentrate and IFDC will process it into 50% SAB-PAPR and have it in Uganda by August 1988. The 250 kg being sent by USAID via air freight will be used. Dr. Zake will be in charge of agronomic tests.

Dr. Fenster also recommended a small quantity of TSP should be made from Sukulu concentrate and returned to Uganda to be used in the above trials.

O.W. Livingston told Dr. Zake that he would arrange for chemical analysis of SSP available in Uganda for these trials. There is some question as to quality since it is quite old, having been made in the original plant at Tororo.

A mechanism was agreed for transferring funds to Uganda to avoid possible loss of IFDC checks. This would be handled through the Manpower for Agricultural Development Project (MFAD). Trevor Arscott was to send a telex to IFDC agreeing to this. This mechanism was later found not to be workable.

C. Cooperation with Ministry of Agriculture, Kawanda Research Station

IFDC is encouraging the cooperation of Mr. John Kavuma in conducting field trials of experimental P products from Sukulu Hills rock and IFDC is awaiting signature of the MOU.

On April 29 a meeting was held with Mr. John Kavuma, Kawanda Research Station, and Mr. Owen W. Livingston with Mr. Isaac Aluba also present. Mr. Kavuma explained that the Ministry of Agriculture (MOA) wants to cooperate in the phosphate testing program, but that officials had not been available to sign the MOU. The source of SSP was discussed and it was recommended that this be discussed with Mr. Tinaako and Prof. Zake. Mr. Kavuma promised to prepare a work plan for O. Livingston to carry to IFDC.

The mechanism for transfer of IFDC funds to the MOA was discussed. O. Livingston and Mr. Aluba suggested a similar arrangement as being done with Makerere University.

O. Livingston told him the products from IFDC are to be in Uganda by August 1988.

Mr. Kavuma provided a tour of the soil testing lab where they are able to measure soil pH, organic matter, P concentration and texture. They provide fertilizer recommendations for all crops.

When the soil is 5.2 they recommend ag lime to raise the pH to 5.7.

D. Cooperation with Ohio State University in the MFAD Project

Through USAID funding IFDC assisted in procurement of initial fertilizer materials to start the project. The Ohio State research can provide valuable information about soil/cropping conditions in Uganda having relevance to IFDC research on phosphate rock, PAPR, SSP and agricultural limestone.

In addition USAID staff are arranging to ship 250 kg of Sukulu Hills concentrate by air and 2000 kg by surface to IFDC. IFDC will pay the shipping costs.

V. Agronomic Results with Igneous Rocks and Modified Forms

Uganda

As indicated previously information on agricultural performance based on igneous rocks is limited. A paper entitled "Literature Review and Economic Analysis of Crop Response to Phosphate Rocks in Eastern Africa" by Edjigayehu Seyoum and John McIntire (ILCA Bulletin 29, December 1987) provides some information on Sukulu Hills phosphate rock and modified forms. Some data are given on the following materials.

URP - Uganda rock phosphate
SOP - Sodaphosphate
SP - Superphosphate
SHP - Seychelles phosphate
NAP - North African phosphate
NRP - Neutralized rock phosphate
MRP - Minjingu rock phosphate
BSG - Basic slag
KF1 - Kenaf no. 1
ERP - Egyptian rock phosph
TRP - Togo rock phosphate
TSP - Triple superphosphat

Some trials indicated that only about half as much of "early available" phosphate was released from URP, compared with other commercially available phosphate rocks and "it became apparent that Uganda phosphate was not suitable for application by itself to annual crops" using wheat as test crop (Jones, cited by Duthie and Keen, 1953). Subsequent work was on calcination of URP - which contained about 25% total P_2O_5 of which 2-4% was citric acid soluble (CAS) - with crude sodium carbonate to make phosphate more rapidly available.

Doughty (cited by Duthie and Keen, 1953) reported that studies of cereals between 1947 and 1951 on laterized and deeply dissected granite and ancient sediment soils in Tanzania showed MRP to be effective; in most experiments benefits from it were only apparent after application for two or three seasons. On lighter-textured upland soils with variable rainfall, TSP was more effective than URP.

Holme and Sherwood (cited by Duthie and Keen, 1953) experimented with URP, SOP and SP on wheat in Kenya during 1948-1950. URP at 290 kg/ha and 580 kg/ha gave negligible responses except in one experiment, and even there it was much less effective than the two other phosphate sources. Similar experiments with maize showed that URP had no appreciable effect in the first year.

Mills (cited by Duthie and Keen, 1953) argued that low responses to phosphate in most of the early cereal trials in Uganda were due to the low levels of its application. He conducted experiments comparing the direct effects on maize and the residual effects on cotton of two P_2O_5 levels of MRP, SP and SOP. At one site with red Latosols, URP and SOP tended to be more beneficial than SP on maize in an abnormally wet year. In trials at another site with similar soil and rainfall conditions, neither URP or SOP or SP increased maize yields significantly, although there was a residual P effect of about an 18% yield increase for all three fertilizers on cotton. At a third site where a yellow Latosol had been fallow for 3 years and then grazed, there was no direct effect on maize and no residual effect on cotton.

This review suggests that URP applied directly in finely-ground form even on acid soils may not provide the initial crop response expected by farmers. It also suggests that alteration by chemical treatment will improve agronomic effectiveness such as calcination with sodium carbonate -- Rhenania-type phosphate. No information on PAPR was given in this review. In order to arrive at a basis for recommendation of various P sources it is necessary to conduct trials to determine average response (AR), where AR is the mean change in yield over the control, for the sources. Then relative agronomic effectiveness (RAE) can be calculated comparing sources. The RAE values can then be converted to relative economic efficienc (REE) by knowing RAE and prices and contents of P_2O_5 in the sources. This infomation is needed to compare phosphate rock (PR), partially acidulated phosphate rock (PAPR) and fully acidulated phosphate rock (SSP). This research forms the basis of agronomic and economic activities being implemented in Uganda.

VI. Economic Comparisons of P. Sources - Sukulu Hills Phosphate

Technology of Production

In the Bearden-Potter study on behalf of TICAF, IFDC served as a sub-contractor for conversion of the Sukulu Hills concentrate into products - SSP, DAP, MAP, TSP and PAPR. A Canadian firm performed the beneficiation evaluation to convert run-of-mine ore to concentrate and this concentrate was shipped to IFDC for processing into the finished fertilizers described above. The technical parameters for production of fertilizers provided by IFDC were used by Bearden-Potter to estimate economics of production. IFDC did not participate in any studies on economics of production of phosphate concentrate or finished fertilizers.

According to a letter from Mr. F. Rwakiseta - Tinaako, Project Manager of TICAF, the project had been found to be economically viable based on an annual production of 50,000 mtpy of P_2O_5.

Originally SSP, PAPR and ammoniated phosphate (4-18-0) were products. According to the same letter the study is to be updated soon to include triple superphosphate (TSP) as one of the product lines. TSP production requires a phosphoric acid plant, not included in the original study, and additional equipment for making TSP. It is assumed that all products will be granular types, since much of the output is to be exported to countries in the Preferential Trade Area (PTA). The original project in a full package was about $100 million. The African Development Bank (ADB) had been requested to extend funds on favorable terms.

Further, according to Mr. Tinaako the cost of SSP would be about US $200 per metric ton, or US $1,000 per metric ton of P_2O_5 in the form of 20% P_2O_5 SSP.

Bearden-Potter and World Bank staff discussed the production and use of PAPR with IFDC and incorporated this aspect into the study. PAPR represents cost savings since as noted previously sulfuric acid consumption is one-half compared with SSP. PAPR was prepared from Sukulu Hills concentrate and shipped to Kenya for agronomic trials; agronomic results from these trials were never received by IFDC. A further cost saving could be realized if Ugandan farmers would accept a non-granular form of PAPR since the cost of granulation would be avoided. Further the non-granular PAPR or ammoniated phosphate could be combined with other materials to make NP and NPK products, including addition of micronutrients ıch as by the following methods.

A. Bulk Blending

One method used, especially in the United States, Guatemala, Malaysia, Brazil, Sri Lanka, Ireland and other countries is to mix dry materials in various ratios called "bulk-blended" fertilizers. The quality of blend depends primarily on the raw materials. Best quality is achieved when each raw material is of the same particle size range; the shape of the particles is not important.

Care must be taken to mix only those raw materials that are chemically compatible or severe caking in storage, even in bags, will occur. For example, a mixture of urea and SSP or TSP should not be used as the mixture will become wet and sticky. A mixture of urea and CAN should not be used for the same reason. Ammoniated superphosphate (SSP or TSP) is compatible with urea, but ammoniation of SSP or TSP will reduce P_2O_5 water-solubility.

B. Compaction

Another method for making NP or NPK, including micronutrients, fertilizers using only dry raw materials is by the compaction process which is practiced in Europe and Guatemala. No drying or cooling is required. The process can accept a wide range of particle sizes and shapes, and with proper mixing of raw materials, produce homogenous forms of NP or NPK. Materials that are chemically compatible as discussed above should be used. The compaction process is more expensive to operate compared with blending.

Either process allows fertilizers to be "tailored" more specifically for each soil/crop situation thus supplying only the amount and type of each nutrient needed. It is relatively easy to produce a wide range of fertilizer grades by either process.

Bulk blending equipment can be fabricated in Uganda (using mild steel) whereas compaction equipment would require a significant foreign exchange component.

Donor agencies may want to import small quantities of bulk blends, along with straight materials to determine farmer acceptance. If this is done, it is recommended that high analysis materials be imported for these trials. Products could later be based on raw materials available from the proposed TICAF plant at Tororo.

C. Small-Scale Basic Phosphate Fertilizer Industry in Uganda

There does not appear to be a good potential for a small-scale basic phosphate fertilizer industry in Uganda based on Sukulu Hills phosphate because: (1) the Sukulu Hills phosphate ore requires a complex and relatively expensive investment for beneficiation to convert the ore into a usable concentrate and (2) the plant should be relatively large to have economy of scale - larger than the demand for P_2O_5 in Uganda. The situation would be different if Sukulu Hills phosphate run-of-mine ore were high grade and medium to high reactivity and could be used without beneficiation for direct application. Further there is no by-product sulfuric acid in Uganda and a plant must be constructed based on imported elemental sulfur. These and other factors were taken into account in the original Bearden-Potter study which according to Uganda Development Corporation Ltd. (letter dated April 26, 1988 to Mr. Ken Lyvers) was found to be viable.

An assessment comparing SSP and PAPR and ammoniated product (4-18-0) was made requiring an investment of about US $100 million by Bearden-Potter. IFDC pointed out to Bearden-Potter at that time the economic savings of PAPR versus SSP. It was also pointed out that the agronomic performance of PAPR must be demonstrated since the product performance is related to the rock type used. Thus the current research being initiated in Uganda with Makerere University and Kawanda Research Station aims to assess agronomic performance of PAPR (50%) based on sulfuric acid acidulation of Sukulu Hills concentrate being supplied by TICAF.

According to Uganda Development Corporation Ltd. a revision of the original study will include TSP as one of the product lines. This will provide a higher nutrient analysis (0-46-0) for distribution in the Preferential Trade Area (PTA). Production of TSP in granular form will require additional investment for a phosphoric acid unit and TSP production unit. Manufacture of phosphoric acid involves reaction of ground rock with sulfuric acid. Manufacture of TSP involves reaction of ground rock with phosphoric acid. In August - October 1984 IFDC performed tests of these processes for Bearden-Potter Corporation using the Sukulu Hills concentrate. Conditions for manufacture were specified. These data can be used in updating the original study. It would be helpful to conduct additional tests to confirm the prior data.

During a similar time period IFDC also performed tests to convert phosphoric acid made from Sukulu Hills phosphate into monoammonium phosphate (MAP, 13-54-0) and diammonium phosphate (DAP, 20-47-0). These products were made by reacting phosphoric acid with ammonia.

VII. Phosphate Feasibility Summary and Conclusions

This consultant was asked to do a reconnaisance level survey of phosphate fertilizer production for USAID with particular emphasis on low cost per ton alternatives such as "direct application of phosphate rock and partially acidulated phosphate rock" as suggested in a consultancy report by Dr. Richard Newberg.

In particular the TOR covered the following items: (1) phosphate ore analysis (2) appraisal of the agricultural sector requirements and potential for increased use of phosphate mineral products (3) fertilizer and limestone supply and distribution analysis (4) identification and appraisal of alternatives for meeting phosphate fertilizer and limestone requirements (5) preparation of a feasibility level report on local production and distribution of rock phsophate, acidulated rock phosphate or alternatives as initial products and (6) preparation of a feasibility level report on production and distribution of agricultural limestone as a separate activity.

Phosphate Ore Analysis

In September 1984 IFDC performed indepth studies of seven processing substage samples, including the concentrate from Sukulu Hills.

With this background information on this deposit no further work appears necessary at this time. The concentrate is well characterized and confirmed to be igneous having a low degree of reactivity.

Prior work was also done to investigate production conditions for SSP, PAPR, TSP, MAP and DAP. Work on SSP, TSP and PAPR is planned, with emphasis on PAPR, to support agronomic research in Uganda through cooperation with TICAF, Makerere University and the Ministry of Agriculture

This consultant was unable to identify any indigenous source of by-product sulfuric acid or low-cost energy sources to render the ore suitable for fertilizer. Energy might be derived from by-product coffee husks. Early work has been reported on Rhenania-type products.

Thus, the feasibility study of Bearden-Potter with Uganda Development Corporation appears to be assessing all potential P products for Uganda.

Further studies of TSP production are needed to complement previous IFDC work due to the specific characteristic of Sukulu concentrate.

Appraisal of Agricultural Sector Requirements

This task is being addressed by the MFAD Project through a contract with Ohio State University. It is assumed that an economic component will be included in this project at the appropriate time. IFDC will assist on an as-requested basis.

Fertilizer Supply

Owing to the specific characteristics of Sukulu phosphate the new program to agronomically evaluate ground PR, PAPR and SSP is needed prior to another indepth economic evaluation. PAPR has already been shown to be a cheaper product compared with SSP and is included in a production scheme. TICAF will produce it if the agronomic effectiveness is satisfactory.

Full Feasibility Study

According to available information a prior indepth feasibility study will be updated. As this consultant understands the TOR, a feasibility study financed by USAID for Sukulu phosphate would be a duplication of effort under the auspices of World Bank funding. The chances of discovering a new phosphate deposit in Uganda having significantly different properties are not good. Discovery of a high grade sedimentary deposit in Uganda would change the whole scenario.

VIII. Agricultural Limestone in Uganda

Indicated Use/Recommendations

A diligent search of all literature available for this consultancy failed to provide any recommendations for use of agricultural limestone in Uganda. Limestone is not referred to in the Crop Production Handbook for 35 crops provided by the Ministry of Agriculture and Forestry, Entebbe, Uganda.

In a report prepared by the Agricultural Secretariat for the year 1987-88 dated December 1987 listing farm gate prices for agricultural inputs and equipment, no price was quoted for agricultural limestone; only fertilizers were listed. Prices were given for ammonium sulfate, SSP, NPK, and CAN.

An older report dated June 8, 1984 by FAO/African Development Bank on Agricultural Reconstruction Project listed only SSP and ammonium nitrate for agriculture and compound mixture CAN, urea and muriate of potash for horticulture with no mention of agricultural limestone.

A March 1987 report of GOU/World Bank Task Force listed only fertilizer as an input with no mention of agricultural limestone. Thus, it appears at present there is no use or recommendation for agricultural limestone.

In discussions with Mr. Ken Lyvers, of USAID, Dr. W. Fenster and Dr. C. Simkins it was indicated that swampland in Area IV in southern Uganda is being reclaimed which is highly acidic due to oxidation of sulfides and will require significant amounts of ag lime now and in the future. The quantity of limestone needed in this area cannot be estimated since this demand will depend on availability and price, which cannot be estimated at this time.

A map in the map sales department in Entebbe indicated limestone deposits (copy could not be obtained) in Tororo and Kasese/Kamwenge (south of Fort Portal). It indicated that lime production had been as follows:

Year	Annual Production, Long Tons
1952	1,030
1953	-
1954	-
1955	8,600
1956	10,000
1957	9,700
1958	6,997
1959	9,622
1960	15,165
1961	13,888

Production

Production of agricultural limestone involves the following steps: (1) quarrying at the mine where large lumps are recovered (2) feeding of lumps into a jaw crusher providing a material 1-1½ inch size; this size may be used for road aggregate and (3) fine crushing of the 1-1½ inch size material to meet ag lime size specifications. A typical size of ag lime is 100% passing 4 mesh and about 50% passing 100 mesh and about 30% passing 200 mesh.

Equipment is available in a wide range of capacities from 1 tph to 30 tph. The units may be operated in a fixed mode at one permanent location or portable for movement from one location to another. Units are available complete with diesel generator and electrically driven motors for remote locations.

The characteristics of the limestone must be known or determined in order to estimate cost of production and type of equipment recommended. One is "hardness" and the other is "abrasiveness". Hardness indicates the power required to break the material and abrasiveness indicates the wear of equipment and maintenance cost (replacement of parts). Crushing of limestone high in silica will cause rapid wear of machines. One simple test for hardness is to scratch the surface with a knife; if it is easily scratched hardness is low. A mirror can be used to test abrasiveness; if the surface of the mirror is etched by rubbing against the stone this indicates a high abrasiveness and high wear on grinding equipment. Actual samples of limestone should be tested to determine the energy required for crushing and grinding. It is also necessary to have a complete chemical analysis of the material to estimate its liming effect such as weight percent CaO, MgO, P_2O_5, Fe_2O_3, Al_2O_3, and SiO_2. IFDC has facilities for testing for these types of materials. In addition major equipment suppliers can conduct a number of standard tests to characterize the stone.

The physical properties of rock are determined by the following tests: (1) absorption (2) compressive strength (3) abrasion (4) specific gravity and (5) toughness. With this information a machine can be selected from a wide range available to produce a desired amount of product in metric tons per hour.

For Uganda production of agricultural limestone cannot be interrelated with the phosphate operation. It was already indicated that Sukulu Hills phosphate is fine size in its natural state and does not require crushing. If Sukulu rock directly applied proves agronomically effective, then the grinding circuit could be used for both phosphate rock and agricultural limestone - Sukulu phosphate also requires fine grinding for use in making SSP, PAPR or TSP.

The potential availability, cost and demand for agricultural limestone in Uganda could not be adequately assessed during this reconnaissance mission by the IFDC consultant. Upon return to the United States the consultant will contact the British Geological Survey which is likely to have information on limestone in Uganda in their data file.

Supply

According to a brief talk with Dr. G.W.K. Ssali of Uganda Development Corporation Ltd. the Uganda Cement Industry Ltd. (UCI) is quarrying limestone for cement production in western Uganda at HIMA and in eastern Uganda at Tororo. Limestone is quarried by blasting, fed into a jaw crusher and finally into a ball mill. The ball mill produces small material for cement.

Samples from both locations were provided to O.W. Livingston and they will be carried back to IFDC for analysis.

According to Dr. Ssali the HIMA near Kasese limestone is relatively soft and contains about 80% $CaCO_3$. He did not know other elements but will find out for the IFDC consultant. Dr. Ssali also thought that reserves of limestone were fully adequate to supply agricultural limestone to Uganda. Further communications are planned as followup to this reconnaissance visit.

Limestone crushing and grinding is a relatively simple and inexpensive operation. For example 30-40 tph ag lime plant complete with diesel-operated generators can possibly be supplied to Uganda for 1-1.5 million US$. Production cost will depend on many factors which cannot be estimated at this time.

<u>Limestone Summary and Conclusions</u>

According to this very preliminary survey supply and production of agricultural limestone in Uganda seems possible. The estimated annual demand is needed based on agronomic tests in order to estimate cost, including distribution.

Thus, the IFDC consultant recommends that USAID consider funding to further evaluate production and use of this agromineral.

IFDC will be pleased to supply a TOR and budget, if requested by USAID. Some local funds are needed for assistance from incountry counterparts to cover expenses they will incur for their input into a detailed study.

ANNEX A

POTENTIAL FOR PRODUCTION OF FERTILIZERS IN UGANDA

Raw Materials

In the past, Uganda produced and exported single superphosphate (SSP). The operation was run by Tororo Industrial Chemicals and Fertilizer Ltd. (TICAF) from 1962 to 1978, when it stopped operations. A feasibility study has been undertaken to start fertilizer production in the future and information in this section is from this study (Bearden-Potter Corp., 1984).

It has been estimated that Sukulu Hills contain reserves of 230.8 million tons of phosphatic rocks (12.8% P_2O_5). At the extraction rate of 124,000 tons per year, reserves project could last for 200 years. TICAF, in its years of operation between 1962 and 1978, only produced 160,000 tonnes of phosphate concentrate from 2.16 million tonnes of ore.

The Proposed Fertilizer Project

The proposed factory operation will produce 50,000 tons per year (P_2O_5) by 1995 assuming it starts operation in 1989 at 58% of design capacity. The estimated capital cost of the project is about US$ 100 million. The project is calculated to have an economic internal rate of return of 14-15% and a financial return on equity investment of 27-28%. Net receipts are estimated at US$ 15-18 million per year after the sixth year. The major products will be single superphosphate and ammoniated phosphate (4-18-0). The main markets are expected to be Kenya, Uganda, and Tanzania, with small quantities going to Rwanda, Burundi, Zaire, Sudan and Ethiopia.

Fertilizer Consumption in Uganda and Surrounding Areas

There i a need to use more inputs for increased food production and fertilizer is one of the important inputs. Use of fertilizers in East Africa is low, except for Kenya where 34 kilograms of all fertilizer nutrients are applied per hectare of arable land compared to Tanzania's 5.6 kgs and Uganda's 0.1 kgs. The use of P_2O_5 is 11 kg, 1.8 kg and nil for Kenya, Tanzania and Uganda respectively.

Fertilizer consumption has grown from 23,000 tonnes of nutrients in 1960 to 187,000 tonnes of nutrients in 1982 in the countries of interest to Uganda. Consumption of P_2O_5 has increased from 5,000 tonnes to 75,000 tonnes in nutrient equivalent during the same period. Phosphatic fertilizer consumption is expected to reach 131,000 tonnes in 1990 and 200,000 tonnes in 2005, with Kenya accounting for over 50 percent of the total.

Kenya uses most of its phosphatic fertilizer on maize and wheat (80% in 1982) and since the demand for these crops is on the increase, it is expected that demand for fertilizers will increase as many farmers notusing it (65% of total area under maize) start using fertilizers. Uganda currently uses very little fertilizer but if the doubling of yields for food crops, as suggested by the Ministry of Agriculture, is to take place then a considerable amount of fertilizer has to be used. The Tanzanian market is not very big as it has its own fertilizer factory which meets half of its demand.

Sales Potential for TICAF's Products

TICAF proposes to sell 67%, 27% and 6% of initial production to Kenya, Uganda and Tanzania respectively. In Kenya, the targeted market is the area west of the Rift Valley where tea, sugar, cotton, maize and wheat are the major crops. In Tanzania, the area targeted is the cotton growing area of Mwanza.

In the long term, TICAF hopes to capture 36% of Kenya's P_2O_5 market, 80% of Uganda's and 10% of Tanzania's market, as shown in the table below:

Projected Sales and Market Share of TICAF's Products in E. Africa

	1990		1995*		2000		2002	
	Tons	%	Tons	%	Tons	%	Tons	%
Kenya	19,000	29	32,000	38	40,000	38	43,000	36
Uganda	8,000	80	11,000	79	19,000	79	23,000	82
Tanzania	2,000	12	2,000	10	3,000	11	3,000	10

*After 1995 the capacity has to be increased beyond 50,000.

ANNEX B

Bibliography

Ministry of Agriculture and Forestry, Crop Production Handbook, Entebbe, Uganda, 1985.

Government of Uganda (World Bank Agricultural Task Force, Final Report Agricultural Inputs, Kampala, Uganda, March 1987.

Agricultural Secretariat, Bank of Uganda, Agricultural Policy Committee, Report on Producer Price Proposals for the Year 1987-88, Vol. II: Price Review, December, 1987.

FAO/African Development Bank Investment Centre, Uganda Agricultural Reconstruction Project Preparation Mission, Rome, Italy, June 8, 1984.

Bearden-Potter Corporation, Tecnical proposal for Sukulu Hills Feasibility Study to Uganda Development Corporation Limited, January, 1982.

Correspondence

To Mr. Ken Lyvers from Mr. F. Rwakiseta-Tinaako, Letter re: Phosphate Fertilizer and Agricultural Limestone Production and Distribution Feasibility Study in Uganda, from Uganda Development Corporation Limited, April 26, 1988.

To American Embassy, Uganda from American Embassy, Abidjan, via Telex re: ADB Program in Uganda, April 19, 1988.