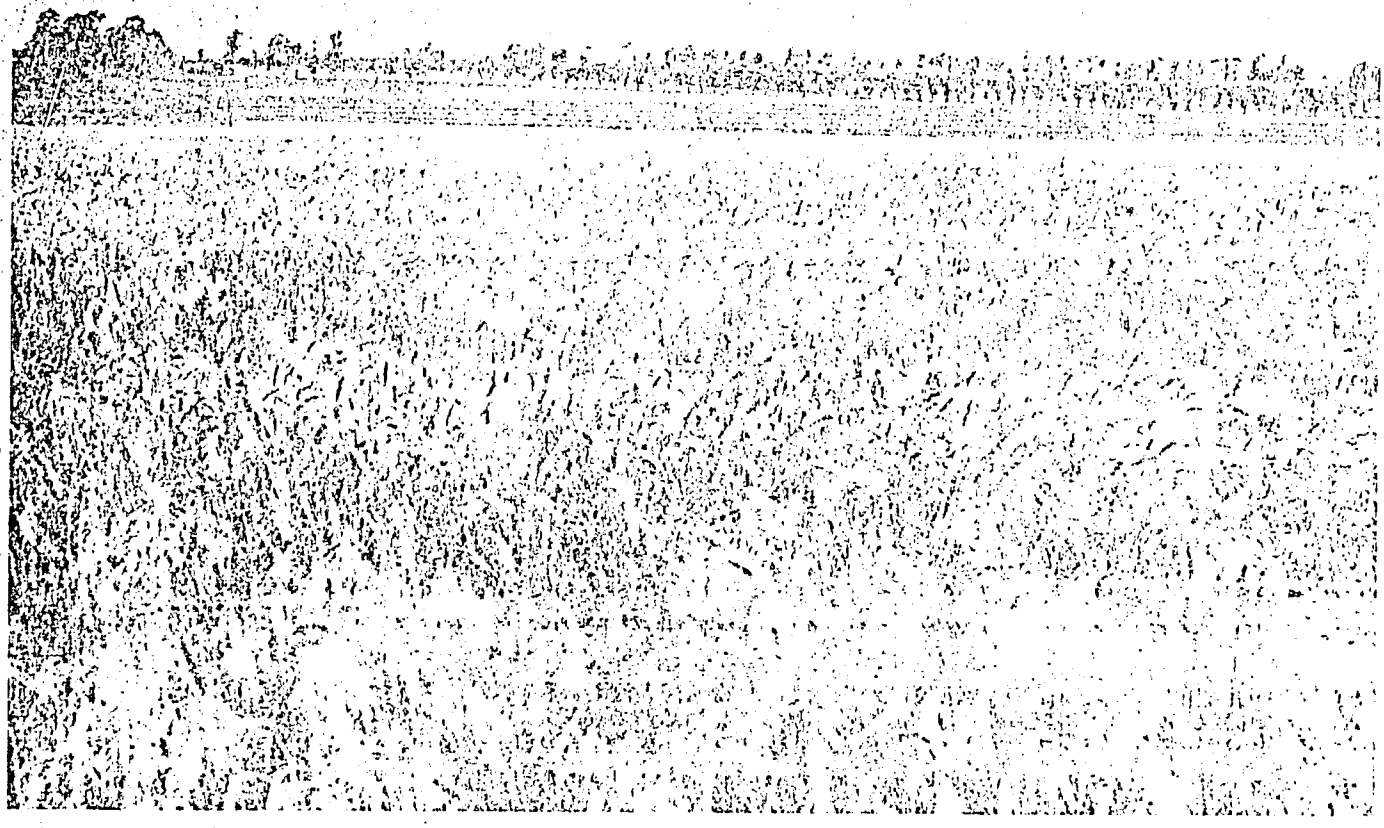
lime, fertilizer & agricultural potential in

Paraguay



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ABBREVIATIONS

AID	Agency for International Development
Al	Aluminum
AS	Ammonium sulfate
ASTM	American Society for Testing Materials
BNF	Banco Nacional de Fomento
BPL	Bone phosphate of lime
°C	Degree centigrade
CaF_2	Fluorite
CIF	Cost, insurance, and freight
cm	Centimeter
DAP	Diammonium phosphate
F	Fluorine
FAO	Food and Agriculture Organization of the United Nations
FAV	Facultad de Agronomia y Veterinaria
FME	Flota Mercante del Estado
FOB	Free on board
g	Gram
₲	guarini; 126 ₲ = $1.00
gal	Gallon
GOP	Government of Paraguay
ha	Hectare
ISFE	International Soil Fertility Evaluation and Improvement Project
K	Potassium
KCl	Potassium chloride
kg	Kilogram
km	Kilometer
km^2	Square kilometer
K_2O	Potash
kwh	Kilowatt hour
LCR	Least cost route
m	Meter
meq	Milliequivalent
MinAg	Ministerio de Agricultura y Ganaderia
mm	Millimeter
mt	Metric ton
N	Nitrogen
NCr	New cruzeiro
OSP	Ordinary superphosphate
%	Percent
P	Phosphorus
P_2O_5	Phosphate
ppm	Part per million
$	United States dollar
TSP	Triple superphosphate
TVA	Tennessee Valley Authority
U.S.	United States of America
USGS	United States Geological Survey
Wt	Weight

Section I

SUMMARY AND RECOMMENDATIONS

Paraguayan agricultural leaders are committed to a program of reducing imports and expanding exports. Expanded production of particular crops is fundamental to the program and lime and fertilizer use clearly must be an integral part of expanded production. Small amounts of fertilizer have been used on several crops for many years. The National Wheat Program, initiated in 1968 to implement the policy of reducing imports, shifted emphasis on fertilizer use to this crop and caused fertilizer use to accelerate.

Along with the expanded use came other changes and problems. The BNF began handling fertilizer and now markets about 90% of all fertilizers used. All fertilizer must be imported. Importation in bags and in small quantities has resulted in high costs.

Wheat is a crucial crop. It is the only one that can be grown on enough fertilized hectares to significantly increase the use of fertilizers. Only a significant increase in fertilizer use will justify adoption of new techniques in handling so that costs can be reduced. Only a reduction in cost will permit fertilizer to be used profitably on wheat and on other crops too. The wheat program has been only moderately successful. Producers who plant 100 ha or more of wheat can obtain 100% loans at low interest rates for land clearing and machinery. There has been a substantial increase in hectarage but yields have varied from nothing to very good. Fertilizer use has not consistently produced a profit. Most soils are extremely acid but limestone has not been used to correct this acidity. Wheat stands and response to fertilizer undoubtedly are affected by the low soil pH.

Present use of fertilizer is estimated at about a thousand mt each of N, P_2O_5, and K_2O. Projected use for 1980 is 16,000 mt of N, 12,800 mt of P_2O_5, and 13,400 mt of K_2O. No lime is used presently but over 150,000 mt is projected for application in 1980. For lime and fertilizer use to increase to this magnitude, problems in procurement, handling, and use must be solved successfully. In order to determine some of these problems and to suggest solutions, a five-member team, representing the TVA's National Fertilizer Development Center, made an in-country study in September-October 1970.

Recommendations ensuing from this study are given here along with a partial explanation of the problem or situation that led to the recommendation. Readers are urged, however, to examine the entire report. Only in this way can an understanding be obtained of the information available to the TVA team, the team's impression of the country, and the reasoning that was used in arriving at a specific recommendation.

Limestone suitable for agricultural use fortunately is located in each of the three main agricultural zones in eastern Paraguay. Some of the stone is quarried and calcined for use in mortar but none is crushed and ground for agricultural limestone. Before prospective producers can evaluate their equipment needs and investment costs, they must know how finely to grind the stone. There are no government specifications. **We recommend that initial specifications for particle fineness of agricultural limestone be as follows: 100% through 8-mesh and 50% through 60-mesh screens.**

Fineness of grinding is only one of the factors that determines the value of limestone as a neutralizing agent. Purity is another factor. **We recommend that the GOP establish quality standards for agricultural limestone based on both fineness of grinding and purity.**

Agricultural limestone is urgently needed in Paraguay. Presently, only calcined lime is available—at a high price as lumps in steel drums. However, there is already an interest in producing agricultural limestone from some of the quarries located between Coronel Oviedo and Caaguazu in central Paraguay. These quarries are virtually at the crossroads for all the agriculture in eastern Paraguay. That is, Coronel Oviedo is located at the junction of the main road (dirt) to the northern agricultural zone and the asphalt highways to agricultural areas to the east, south, and west. Although transportation costs are high to some of the remote areas (lime trucked to Pedro Juan Caballero would cost $24/mt), these quarries would be the most economical for supplying agricultural limestone to all the country until quarries could be developed in other areas. **We recommend development of the central Paraguayan agricultural lime industry as quickly as possible.**

Only one quarry, temporarily abandoned due to flooding of the Rio Tebicuary, was located in the southern agricultural zone. The quarry also is located quite near some of the new and very large wheat farms but it could not be sampled adequately. **We recommend that the GOP investigate the size and quality of limestone deposits at Villa Florida and any other locations in the southern zone. Private interests should be encouraged and assisted to**

develop an agricultural lime industry in southern Paraguay if the deposits are large enough.

In northern Paraguay the main limestone deposits are located on the Paraguay River. Three quarries are producing calcined lime which is shipped down the river to Asuncion. No roads connect these quarries to the farming areas but agricultural lime could be transported down river to Concepcion and San Pedro and then trucked to the farming areas. The two private quarries (at Itapucumi and Itacua) contain only calcitic limestone but the GOP quarry at Vallemi contains both calcitic and dolomitic stone. However, it is possible that one of the private quarries will have several thousand tons each year of stone already crushed to less than 1.5 cm in diameter. In contrast to the mammoth deposits along the river, another deposit has been reported across the country at Pedro Juan Caballero. No additional information is available but the location is advantageous to many farmers. **We recommend that private interests develop an agricultural limestone industry for northern Paraguay with quarries located at Itapucumi and Pedro Juan Caballero—if the deposit at this latter location proves feasible for development. The GOP should be prepared to produce lime at Vallemi if the Itapucumi venture does not materialize.**

Many countries manufacture their own fertilizers, usually from indigenous materials. However, if fertilizer needs are high enough, costs can be reduced by manufacturing fertilizer from either imported raw materials or imported intermediates. Paraguay has no known deposits of minerals needed for the manufacture of fertilizers. Therefore, the cost of producing phosphate fertilizer was determined on the basis of imported raw materials. Phosphate in the form of TSP can be imported at about half the cost of manufacturing it as OSP. **Unless both phosphate rock and elemental sulfur are discovered in commercial deposits in Paraguay, we do not recommend that phosphate fertilizer be manufactured within the country.**

Before 1968 Paraguay had never imported more than 1,500 mt of feritilizer in a year. Such small purchases hardly qualify as major imports and the country could not afford to have special facilities for handling fertilizers. Therefore, the fertilizer arrived in bags. Bagged fertilizers are expensive in Paraguay. A kg of nitrogen costs the farmer about 71₲ (over 22 cents per pound). Bulk fertilizers would cost only a little more than half this much. **We recommend that Paraguay import fertilizers in bulk form just as soon as facilities can be made available to handle them.**

Fertilizers for importation can be purchased from various producers throughout the world. When purchased with U.S. loan funds, however, U.S. laws require that 50% of the fertilizer be transported on U.S. flagships. Charter rates for these ships are much higher than those for non-U.S. flagships. Although sales of U.S. fertilizers are needed, the following recommendation is made from th view of what is best for Paraguay. **We recommend that a much fertilizer as possible be purchased with private fund AID funds should be used when competitive bidding resul in delivered costs that are lower, even though transpo tation in U.S. flagships is provided, or as a last resort fo funds.**

There are several alternative routes for importing ferti izer into Paraguay. The LCR depends upon rates charge by the different carriers and the destination of th fertilizer. Presently, Asuncion is the destination of nearl all fertilizer; farmers from all over the country must sen trucks to this city for fertilizer. Rarely do they purchas enough to completely fill the truck and so real transpo tation costs are excessively high. On the other hand, warehouses were to be dispersed throughout the country fertilizer could be delivered from the ocean ports directl to these warehouses using very large carriers loaded t capacity. When this system was examined, it was found tha the LCR to some locations involved importation throug Paranagua, Brazil, while other locations were benefited b shipment through Buenos Aires. Transporting bulk fertilize from the two ocean ports to six selected distributio centers—two in each agricultural zone—by LCR involve four distinctly different common carrier/import routes. Al three common carriers (truck, rail, and inland boat) wer utilized for one location or another. As a result of usin LCR the fertilizer delivered to Coronel Oviedo by truc from Paranagua is only a few cents per mt of plant nutrien more than the cost of the same material delivered t Paraguari from Buenos Aires via boat to Asuncion and the truck the rest of the way. **We recommend that fertilizer b warehoused throughout the country rather than a Asuncion and that the fertilizer be imported via the LCR for each of the distribution centers.**

Many technical problems will be encountered as th country moves into a program of handling fertilizers in bulk. Equipment to handle bulk fertilizers will be needed at the ports at Asuncion and Encarnacion. Similarly, some modifications in ships and barges would be desirable to better adapt them to transporting bulk fertilizers. It was beyond the scope of the present report to specify the exact items, size, and cost of such equipment and modifications. **We recommend that a detailed study be made of the facilities and equipment needed to handle fertilizers in bulk from the ocean ports to the warehouses in Paraguay.**

Generally, importing mixed fertilizers costs more than straight materials because of the additional operations required to bring all the necessary ingredients together in one location and then combine them into a preselected grade. By locating a bulk-blending plant near the use area, plant nutrients can be purchased any place in the world at the lowest cost and then blended together to the exact $N:P_2O_5:K_2O$ ratio recommended from a soil test. We

recommend blending in Paraguay of the bulk fertilizer imported into the country.

A single bulk-blending plant is beset with the same difficulties as a single warehouse. Economy of distribution must be considered simultaneously with economy of scale and size of the market. Since wheat is the crucial crop, fertilizer needs of wheat can be used to measure the market. Market areas are long, narrow rectangles centered on the few main highways. Haul distances for blended fertilizers are high and so are the costs. This suggests that additional bulk-blending plants should be built just as fast as increases in fertilizer use will permit. **We recommend that six bulk-blending plants be constructed in eastern Paraguay during the next decade.**

Many kinds of blenders can be used and the degree of sophistication or mechanization can vary widely for bulk-blending plants. However, the amount and kind of equipment makes up only a minor share of the cost of blending bulk fertilizer. The major factor is the amount of material that must be in storage—and especially the amount of unblended raw materials. These materials must be protected from the weather and this kind of storage is expensive. Unfortunately, Paraguay is a landlocked country located at a very great distance from producers of fertilizers. In order to ensure that fertilizers are available when needed by farmers, large amounts probably will have to be stored for a considerable length of time. This requires an excessive amount of storage capacity and also increases working capital to very large sums. These, then, become major items contributing to the cost of blending fertilizers. **We recommend that a careful study be made of the scheduling of fertilizer shipments because they affect the amount of storage capacity and working capital needed by a bulk-blending plant.**

The present fertilizer marketing system consists of both a private and a public sector. Many firms have entered the private sector in past years but only a few survived. The market was too small. Finally, BNF, an entity of the GOP, became a distributor for the GOP agricultural development programs. If fertilizer use can be increased successfully through the National Wheat Program, operating bulk-blending plants and marketing their products becomes a full-time occupation. Some of the fertilizer that is blended can be applied directly to fields using field applicators designed to broadcast bulk materials. (These same applicators can be used to apply agricultural limestone.) Probably wheat farmers with large hectarages will spread bulk fertilizers. Most other farmers will want bagged fertilizers and so each blending plant also needs a bagging machine. Wheat is fertilized mostly in the fall but most other crops are fertilized in the spring. Thus, blending plants must produce for two use seasons and marketing becomes a full-time occupation requiring specialized knowledge. **We recommend that private industry operate the bulk-blending plants and market the fertilizer in Paraguay.**

At least three types of credit are needed if Paraguay is to expedite agricultural development through judicious use of lime and fertilizer. **We recommend that BNF, with or without the assistance of AID/Paraguay, provide monies for physical facilities needed to expand the lime and fertilizer industry, provide credit for private companies to import bulk fertilizers, and provide production credit to farmers.**

Expanded fertilizer and lime use will cause expansions in all aspects of the fertilizer industry and in many peripheral areas. More fertilizer salesmen will be needed, extension agents will be contacted more frequently with questions about lime and fertilizers, credit fieldmen will need to know more about how these materials should be used, men must be trained to operate and work in bulk-blending plants, and researchers at the FAV and the MinAg experiment stations must become familiar with new methods of handling and applying fertilizers in bulk. Above all, many farmers must be taught how to use fertilizers economically and effectively. **We recommend that a series of short courses be planned and conducted for the various groups that will become involved in the production, marketing, and use of lime and fertilizer.**

Benefit/cost ratios based on the current price of crops and the response of crops to fertilization show that bagged fertilizers are too expensive to produce a profit except in a few special situations. Only after the cost of fertilizer has dropped due to bulk handling will fertilizer use generally become profitable. However, crop prices must continue at about the current level or the cost of fertilizer must be subsidized for this to happen. **We recommend that GOP support the price of crops (especially wheat) rather than subsidize the cost of fertilizer.**

Farmers who acquire large, contiguous holdings for wheat production must make large investments in clearing and preparing the land, in agricultural machinery, and in storage facilities Long-term loans at low interest rates are available for this purpose. Money can also be borrowed for the purchase of fertilizer and seed but the interest rate is 10% and the loan period is only 8 or 9 months. When some of the land does not produce a crop because of soil acidity and low fertility, an extra burden is placed on the remaining hectarage to pay off the loans and produce a profit. **We recommend that the original capital investment loan for farmers be broadened to include the initial application of lime needed to correct the extreme acidity of many soils and to include a corrective application of phosphate and potash fertilizer.**

The GOP already has liberated some of the customs and duties on agricultural products that must be imported. Others have been reduced but some have been overlooked. Truckers point out, also, that regardless of the size of the fee, they frequently spend many hours waiting to clear

customs and inspections but can expedite clearance by paying extra fees. We recommend that GOP review its customs and duties on fertilizers and again eliminate and reduce as many as possible; further, efforts should be made to expedite the orderly movement of fertilizer into the country.

As the price of fertilizer drops so that use can be extended profitably to more farmers and more crops, a broad range of techniques must be used to inform potential customers about fertilizers. Fertilizer companies already are using demonstrations and soil test recommendations for this purpose. We recommend that all companies perform educational services and that government officials cooperate in supplying needed information to company officials.

Much applied research is needed with fertilizers in Paraguay. Since most of the fertilizer will be used on wheat for the next several years, it is on this crop that the research should be conducted first. In two or three more years, enough research will have been completed on wheat—and perhaps another crop or two as well—that demonstrations can be started. Under no circumstances should an attempt be made to use demonstrations as a replacement for research. Their purpose is to demonstrate proven facts, not to collect new ones. We recommend that fertilizer demonstrations be postponed until the extension staff has gained more knowledge and experience with fertilizers and research personnel has completed more applied research.

Large variations in limestone quality are possible. These depend upon how finely the material is ground and the chemical composition of the limestone. Without national standards, each producer must establish his own standards and could, of course, change the standards any time he desired. We recommend the passage of laws that specify the minimum standards for chemical composition (calcium carbonate equivalent) and fineness of grinding for agricultural limestone, that define limestone quality or neutralizing power in terms of both chemical composition and fineness of grinding, and that specify penalties for mislabelling of limestone as to quality.

The preceding recommendation presumes that there will be some type of regulatory authority that can collect limestone samples and analyze them in a laboratory. We recommend that the head of the laboratory services and the chief inspector be sent to the United States to study techniques and procedures.

Further, we recommend that the laboratories and inspection services for agricultural limestone be under the control of and operated by the MinAg.

Anytime that two or more ingredients must be mixed, as in the bulk blending of fertilizers, there exists a chance for errors. When a farmer fails to obtain the growth or yield he expects from a fertilized crop, he frequently blames the fertilizer rather than poor management. Many of these problems can be avoided and others can be answered satisfactorily when official samples are collected and analyzed. We recommend the passage of laws that define commercial fertilizers and establish the standards of quality that shall be enforced upon all handlers.

As with limestone samples, the collection techniques and equipment and the analytical procedures used must be carefully prescribed. We recommend that a team visit the United States and other countries in Latin America to study the procedures used and to recommend those that will best serve Paraguay.

It would be expedient for the limestone regulatory services and the fertilizer regulatory services to be a single agency or at least for both to report to the same authority. We recommend that the laboratories and inspection services for fertilizer be under the control of and operated by the MinAg.

Although no igneous rocks rich in apatite were observed during this brief investigation, it cannot be said that they will not be found. Careful investigation by detailed geological mapping, magnetic surveys, radioactivity surveys, heavy mineral surveys, and geochemical soil mapping of alkalic igneous rock complexes may reveal commercial concentrations of phosphorus and other valuable minerals. We recommend that the work begun at Sapucai be continued in a more detailed manner. The Acahay-La Colmena area should be investigated before returning again to the Sapucai area.

The presence of limestone deposits in each of the three major agricultural zones is of major importance to the continued development of agriculture. Present knowledge of these deposits is very inadequate. Some are not even listed on geological maps of the area in which they are located. We recommend that the extent and nature of the limestone deposits in each of the three agricultural zones be fully explored.

Section II

INTRODUCTION

At the request of the AID Mission to Paraguay, a two-man team from TVA's National Fertilizer Development Center spent 10 days (January 18-29, 1970) in Paraguay. This team was composed of Donald L. McCune and John T. Shields of the International Fertilizer Development Staff. They advised AID/Paraguay on the scope of work for a detailed fertilizer study and helped prepare a draft of a request for a U.S.$1.5 million loan to be used in importing fertilizers. The followup team was in Paraguay September 20-October 30, 1970, in order to evaluate fertilizer and associated soil fertility problems.

BACKGROUND

Many reports concerning Paraguay start with a statement that this is one of two countries in South America that has no direct access to an ocean port. The small size (406,752 km^2 or comparable to California) is next emphasized. A population pressure on land near the country's capital of Asuncion, a chaotic political and military history prior to the present government of President Stroessner, and a lack of exportable mineral resources are among the additional factors used to explain why Paraguay is classed with the developing rather than the developed countries. These facts cannot be denied, yet most could be the effect of as well as the cause of delayed development. Arnold, in his strivings to arrive at an agricultural policy statement for the country, delved deeply into the country's social and economic history. One statement stands out:

> ...most of the people throughout the 430 years since the settlement of Asuncion have never received positive rewards for their efforts to produce beyond subsistence.(18)

In contrast, the past decade has been noted as one of remarkable change in the attitude of the Paraguayan business community. New leaders have emerged in the major enterprises and economic associations of the country. They are dedicated to private sector development and are cooperating with the government in formulating appropriate policy and legislation. The results are apparent in recent expansions in infrastructure, new private investments, increasing participation in international affairs, surging tourism, and the incursion of foreign businessmen (48). It is against this background, then, that AID is assisting the GOP to constantly review its agricultural development programs.

Paraguay had a population of 2,303,500 by 1969 with an annual growth rate estimated at 3.1%. The rural population is expanding at a rate of 3.7% annually and now makes up 63.5% of the total. Traditionally, 60% of the population has lived in or within 150 km of Asuncion but this also is changing. The population in the north and east of the country has been growing at a rate of 7% annually (17, 51).

Usually a net exporter, in recent years Paraguay has become a net importer. Exports in 1968 were valued at $47 million. Crops and fruits comprised 38% of the total and meat and forest products made up the balance. Vegetable oils (palm, castor bean, and tung) and tobacco are the leading export crops; others are essence oils, cotton, yerba mate (the national drink similar to tea), fruit, and sugar. Over 10% of the 1968 imports were food products. Wheat and wheat products required nearly $6 million of the $7.9 million expended in this category. Milk products accounted for another $0.5 million (17, 51). GOP is concerned with these trends and is attempting to reverse them. A National Wheat Program has been initiated to increase domestic production and reduce imports. A National Tobacco Program seeks to expand exports of this crop. In both cases, use of fertilizer is an alternative to expanding hectarage.

The small amount of chemical fertilizer currently used in Paraguay must be imported. The cost is high and use is not expanding very rapidly. Only high-valued crops can be fertilized profitably. High-valued land, such as that near Asuncion and paved roads, might also be fertilized but profitability is less certain. The emphasis to be given to fertilizer use in agricultural development has been questioned because other enterprises possibly would produce higher or faster rates of return on GOP investments of money and energy. Failure to obtain harvestable stands of wheat on some newly cleared soils has created additional questions about basic soil fertility needs and the types of research needed to define these needs. Additionally, reports of apatite as an accessory mineral in intrusive rocks near the center of the agricultural area and huge deposits of limestone far removed from the agricultural areas provided some possibility for domestic mineral resources of use in an improved soil fertility program.

Paraguay, then, has some potential for expanding its use of fertilizers. Lack of experience with fertilizers created local uncertainties about proper techniques for evaluating fertility problems, fertilizer use, and economical methods of acquiring needed plant nutrients. Thus, AID requested TVA's National Fertilizer Development Center to make an in-depth study.

OBJECTIVES

The specific objectives of the study were to:

A. Determine the status of fertilizer use by crop and region. Develop a requirement and schedules for implementation of fertilizer experimental trials by the National Extension Service.

B. Recommend types of fertilizer that will suit the requirements from an agronomic and economic viewpoint and determine how these materials should be obtained, keeping in mind there are no basic materials or blending facilities in the country.

C. Advise on marketing and distribution systems that will provide needed fertilizer materials for farmers at reasonable prices. This will include advice on incentive programs, fertilizer education, credit, and other services that encourage widespread use.

D. Estimate the rate of expansion of fertilizer use through 1980.

E. Indicate the types of fertilizer industry that can be justified at various levels, including personnel and capital requirements.

The scope of the study was outlined in more detail:

1. To give guidance on the types, ratios, and the amount of fertilizer by region and by major crops that can economically be used in Paraguay through 1980.
2. To suggest the roles of the public sector, the private sector, and cooperatives in providing credit and in the importation, blending and/or mixing, storage, distribution, and marketing of fertilizers and liming materials.
3. To work with organizations active in retailing of fertilizers and liming materials to help assure that the most effective methods, techniques, and approaches are being adopted and used in their education and sales programs.
4. To advise on types of equipment that would be needed at various levels of use to furnish, blend, distribute, market, and apply fertilizers.
5. To help set up specifications and standards (quality control) for fertilizer and liming materials and to suggest the best method of assuring that these standards are met.
6. To examine, through ground reconnaissance and by testing, known apatite deposits located near Sapucai, Paraguay.

To accomplish these objectives, a multidisciplined team collectively spent more than six man-months in the country gaining firsthand knowledge of conditions and attitudes. Each member of the team was responsible for collecting and interpreting information in his sphere of competence.

James R. Lehr, chemist, was responsible for selecting mineral samples during the field reconnaissance of possible phosphate rock and limestone deposits. He also supervised analysis of the samples in the TVA laboratory facilities.

Owen W. Livingston, chemical engineer, was responsible for evaluating plans and facilities for the importation and handling of fertilizers.

Darrell A. Russel, agricultural economist and team leader, was responsible for evaluating the cost factors in obtaining and using fertilizers.

Donovan L. Waugh, regional director for North Carolina State University's International Soil Fertility Evaluation and Improvement Project, served as agronomist. He was responsible for evaluating the agricultural production potential and for estimating the lime and fertilizer requirements for the long-range use of the program.

Lawrence V. Blade, geologist, U.S. Geological Survey (Brazil), was attached to the team for over three weeks. He was responsible for mapping and describing geological features observed during the field reconnaissance for phosphate and limestone.

The entire team collaborated in the preparation of this final report.

Section III

PARAGUAYAN AGRICULTURE

GEOGRAPHY, CLIMATE, AND SOILS

Paraguay has a land area of about 40.7 million ha. The Paraguay River, which runs from north to south, divides the country into two major regions with 60% of the land falling into the western region and 40% in the eastern region (figure 1).

Western Paraguay, known as the Chaco region, is a great plain built up by the deposition of alluvial material from the Andes Mountains to the northwest. The area ranges from lowland and swamps along the Paraguay River to a very arid and somewhat inhospitable plain to the west. Rather large temperature and rainfall fluctuations occur across the region giving rise to xerophytic forest vegetation in the eastern Chaco and brush desert or spiny forest in the drier western Chaco. While generally deficient in rainfall, especially in the western part, occasional heavy rains cause flash floods. The importance of the area agriculturally is limited primarily to extensive livestock production; the water deficit is such that discovery and development of good water sources would be a prerequisite to more intensive agriculture.

Figure 1. Departments in western and eastern Paraguay

East of the Paraguay River is the relatively heavily populated area known as Oriental Paraguay. Elevations range from 50 to about 800 m, and the land is gently rolling except along the eastern section. Here a rougher relief results from several systems of low mountain ranges. The natural vegetation along the Parana River on the eastern border of the country is humid rain forest, whereas most of the remainder of eastern Paraguay is humid forest. Eastern Paraguay offers considerable agricultural potential, as shown in table 1, with 90% of the land being suitable for some kind of agricultural use. In production of the important crops, eastern Paraguay accounts for 90% of the sugarcane, 95% of the cotton, and 97% or more of the corn, mandioca, rice, tobacco, and wheat.

The nonstable balance between the cold masses of air from the south and the very hot tropical air from the north brings about sharp variations in both temperature and rainfall although the net effect is not as hostile in eastern Paraguay as it is in the Chaco. The lowest period of rainfall occurs from May to September; this is also the period of coolest temperatures. Evaporation rates are quite high throughout the country but rainfall varies from very low in the west to high in the east. As a result, the annual excess

Table 1. Soils of Eastern Paraguay by Region and Class (18)

Region	Soil class[a] I	II	III	IV	V	Total	Percent
	1,000 ha						
Central	400	580	1,060	260	0	2,300	14
Itapua	920	150	420	160	0	1,650	10
Misiones-Neembucu	80	–	2,485	0	0	2,565	16
Alto Parana	2,790	1,385	780	430	0	5,385	34
San Pedro - Concepcion	590	1,030	1,590	430	410	4,050	26
Total	4,780	3,145	6,335	1,280	410	15,950	100
Percent	30	20	40	8	2	100	

[a]Soil classes:
Class I – Suitable for intensive use.
Class II – Suitable for moderate agriculture and livestock use.
Class III – Suitable for extensive use, mainly livestock farming.
Class IV – Limited to forest use.
Class V – Not identified.

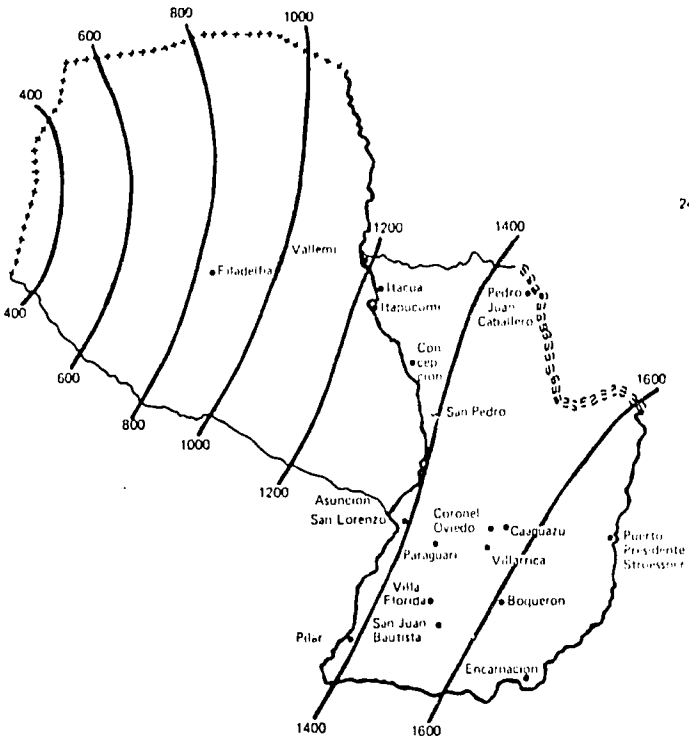


Figure 2. Mean annual rainfall (mm), 1941-1960

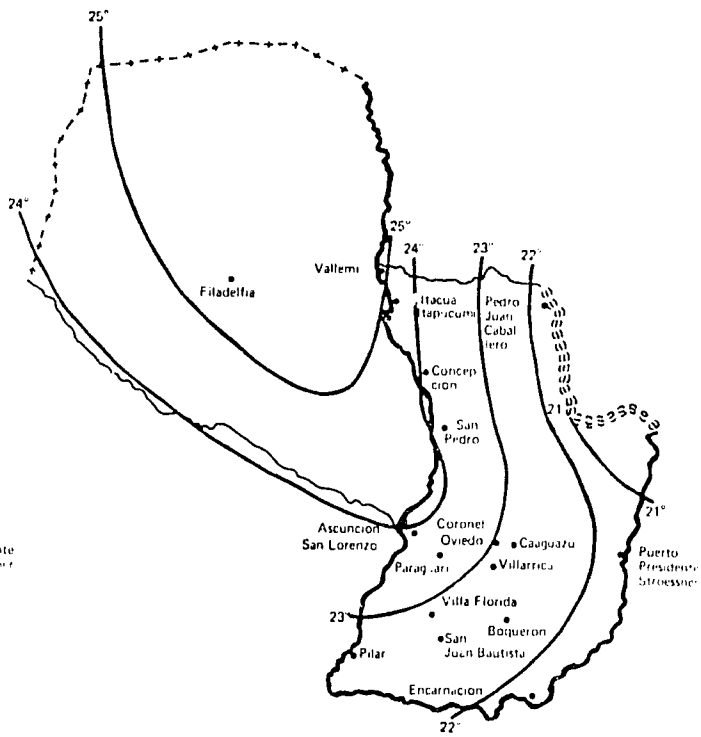


Figure 3. Mean annual temperature (°C), 1941-1960

of water ranges from 324 mm in the east to a deficit of 533 mm in the west. Figures 2 and 3 show the rainfall and temperature patterns.

The soils of the Chaco region have been studied very little but the information available indicates that many are affected by salts. Native fertility probably is better than in the eastern section of Paraguay.

The soils of eastern Paraguay can be divided into two major groups: soils of the uplands and soils of the lowlands. The upland soils include the latisols and reddish-brown laterites developed over basaltic rock and the red and yellow podzolics developed on Misiones sandstone. Two other small groups of upland soils are those derived from calcareous and from granitic parent material. The soils of the lowlands include the recent alluvial materials and the hydromorphic soils (humic gleys and planosols). A general soils map for eastern Paraguay is given in figure 4.

The fertility status of the soils of eastern Paraguay, as determined by tests for available phosphorus and potassium, is given in appendix table A-1. The predominance of soils low in phosphorus is noteworthy. The soil test results show that almost 90% of the samples analyzed were

Knowledge of nutrient levels and soil capabilities is a key to better farming.

deficient in available phosphorus (35). Marked response to applications of phosphorus fertilizer confirms this often-reported deficiency. Potassium fertility is more variable, tending to be higher in lateritic soils with a high clay content than in sandy loam red and yellow podzolics. Nevertheless, 50% of the soil samples were deficient in available potassium (35). Response data for potassium have not been obtained as frequently as for phosphorus. Differences in soil management readily alter these general trends in soil fertility and make a correlation between soil classification and soil fertility unreliable as a guide to fertilization.

The number of soil samples analyzed to date for each department is not large enough to permit fertilizer requirements to be considered on a departmental basis. However, eastern Paraguay can be divided into three agricultural zones. These are based on accessibility by highway rather than on a geological, climatic, or other natural basis. When soil test data are pooled according to these zones, two distinct fertility patterns are apparent (table 2). In the northern zone two-thirds of the soils requiring fertilizer need both phosphorus and potassium and only 30% requires only phosphorus. (Soil tests do not indicate the nitrogen status.) In the central and southern zones, the division between these two classes is nearly equal. As table 2 shows, the percentage of soils needing only phosphorus increases from north to south.

Soil test data for soil acidity are given in table A-2 and summarized by zones in table 3. Soil pH is the only index available to evaluate soil acidity. Soils below pH 5.0 probably will have between 1.0 and 2.0 meq Al^{+3}/100 g soil (analysis of a limited number of samples indicates this level of aluminum) and would probably require 2 mt/ha or more of lime on most annual crops. On the other hand, soils with pH 5.1 or higher may require only 1 mt/ha of limestone on some annual crops and perhaps none for some crops. More detailed information will be required to make specific liming recommendations. Stratifying the samples into agricultural zones does not produce significant pH trends. There is a slight increase in the percentage of soils above pH 6.5 from south to north (table 3) but all three zones have nearly identical percentages of soils needing lime (pH< 5.5).

Table 2. Soil Fertility Pattern for Eastern Paraguay (from table A-1)

Agricultural zone	Percentage of soils deficient in[a]		
	Both P & K	P only	K only
Northern	63	27	3
Central	42	43	2
Southern	40	52	3
Weighted mean	47	42	3

[a]Percentages do not total to 100 because a few soils contain medium to high amounts of available P and K.

Table 3. Soil Acidity Pattern for Eastern Paraguay (from table A-2)

Agricultural zone	Percentage of soils in each pH range			
	≤ 5.0	5.1–5.5	5.6–6.4	≥ 6.5
Northern	32	24	27	17
Central	27	27	34	12
Southern	25	28	36	11
Weighted mean	28	26	33	13

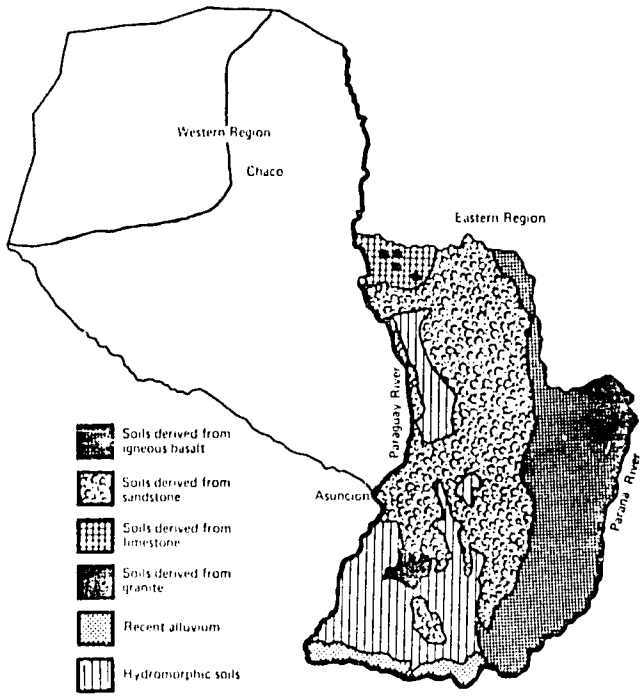


Figure 4. General soils map of eastern Paraguay

More than half of the agricultural soils need liming.

CROP DISTRIBUTION, YIELDS, AND EXPORT VALUE

The traditional or subsistence crops of corn, mandioca, beans, and wheat or rice occupy many thousands of hectares in Paraguay. Other major crops, produced both for domestic consumption and export, are cotton, tobacco, and sugarcane. During the past three years there has been a marked increase in the production of wheat, the principal deficit crop. Because of the strong increase in production of soybeans, Paraguay will approach self-sufficiency in this crop in 1970.

The extent of the cultivated area and yield per hectare of principal crops in Paraguay is given in table 4. The only crops showing a trend to increase in hectarage are wheat, soybeans, and, to a lesser extent, tobacco. Soybean and wheat areas estimated for 1970 were 20,000 ha and 40,000 ha respectively. Yields per hectare are apparently increasing for wheat and soybeans, largely due to the better wheat varieties and initiation of fertilization. Per hectare yield increases in onions, potatoes, and sweet potatoes suggest that these crops may also be receiving some fertilizer, although only on a fairly small part of the total area.

Table 4. Cultivated Area and Yield of Principal Crops in Paraguay, 1965-1969 (51)

Crop	1965		1967		1969	
	Area	Yield	Area	Yield	Area	Yield
	1,000 ha	mt/ha	1,000 ha	mt/ha	1,000 ha	mt/ha
Alfalfa	5.0	3.60	5.2	3.60	4.8	3.80
Beans	35.6	0.75	37.0	0.70	30.9	0.65
Corn	161.5	1.30	173.0	1.30	127.5	1.20
Cotton	56.7	0.74	38.2	0.70	60.0	0.68
Mandioca	108.0	14.00	97.3	15.00	103.3	15.00
Onions	3.0	4.70	3.4	5.00	2.0	8.50
Peanuts	22.6	0.85	24.4	0.85	21.6	0.75
Peas	3.7	0.60	4.2	0.60	4.3	0.60
Potatoes	2.1	4.00	2.0	5.00	1.3	7.80
Rice	8.0	2.70	7.2	2.50	13.2	2.30
Soybeans	11.2	1.60	12.8	1.40	12.2	1.80
Sugarcane	26.8	37.00	26.0	38.00	23.5	35.00
Sweet potatoes	10.5	9.50	9.1	9.87	8.8	10.70
Tobacco	19.6	1.25	10.8	1.25	20.0	1.20
Wheat	10.8	0.65	8.3	1.10	31.6	0.95
Total	485.1	–	458.9	–	465.0	–

Crop area by department is shown in table A-3 for wheat, sugarcane, corn, cotton, rice, tobacco, and vegetables. The distribution of these crops within the three agricultural zones in eastern Paraguay is given in table 5. Wheat is divided evenly among all three regions but the other crops are grown primarily in the central and southern zones.

Crop areas for coffee, citrus, yerba mate, tung, and other tree crops are not included in the MinAg Manual of Statistics. Income from exports of coffee and tung oil amounted to $2,475,000 in 1969, and these exports will probably increase. Income from exports of fruit and yerba mate has fallen off the past four years and was valued at $861,000 in 1969. A summary of the value of export crops between 1966 and 1969 is given in table 6.

FARM SIZE AND DISTRIBUTION

Cattle ranches in Paraguay are generally in units of 1,000 ha or more but crop farms tend to be small, subsistence units. Nearly half of the farm operators are on units of less than 5 ha (table 7). These small farms (*minifundia*) are concentrated around Asuncion in the Departments of Central, Cordillera, Guaira, and Paraguari (table 8). The population density in these four departments, excluding Asuncion, exceeds 47/km^2; outside this area the density averages less than 6/km^2 (51). Despite the apparent population pressure on land in the minifundia area, nearly 800,000 ha (53.2% of the total area) is in holdings of 1,000 ha or larger (18). Thus, pressure for land is very artificial and appears to relate directly to infrastructure. Most farms in the minifundia are located within 10 km of a highway or main road.

Table 5. Distribution of Principal Crops in Eastern Paraguay in 1969 (from table A-3)

Agricultural zone	Wheat	Cotton	Tobacco	Corn	Rice	Sugarcane	Vegetables
				ha			
Northern	10,620	3,600	3,550	14,600	480	1,270	190
Central	11,770	32,900	12,020	69,250	3,260	17,720	2,185
Southern	9,210	23,500	4,430	43,650	6,505	4,460	925
Total	31,600	60,000	20,000	127,500	10,245	23,450	3,300
				% of total ha			
Northern	33.6	6.0	17.8	11.4	4 7	5.4	5.8
Central	37.2	54.8	60.1	54.3	31.8	75.6	66.2
Southern	29.2	39.2	22.1	34.3	63.5	19.0	28.0

Slash and burn still is a common method for clearing a new farm.

Table 6. Value of Crop Exports 1966-1969 (29)

Crop	Year 1966	1967	1968	1969
	$1,000			
Tobacco	2,475	3,370	4,523	5,626
Cotton	1,988	2,290	1,395	3,205
Tung oil	2,578	2,930	2,236	2,422
Essence of petit-grain	1,201	1,337	1,526	1,592
Coffee	1,961	1,456	1,896	953
Tartago (seed)	629	412	870	868
Yerba mate	1,647	633	616	585
Fruits	609	386	466	276
Corn	47	283	99	1
Sugarcane	5	1	25	17

Table 7. Number and Size of Farm and Ranch Units, Crop Year 1960-1961 (3)

Area under cultivation ha	Number of farms	Percent total	Cumulative percent
Without arable land	2,807	1.7	1.7
0.1-0.4	4,480	2.8	4.5
0.5-0.9	8,887	5.5	10.0
1.0-1.9	24,364	15.2	25.2
2.0-2.9	24,694	15.4	40.6
3.0-3.9	21,974	13.7	54.3
4.0-4.9	17,996	11.2	65.5
5.0-9.9	40,843	25.3	90.8
10-19.9	11,766	7.3	98.1
20-49.9	2,489	1.5	99.6
50-99.9	328	0.3	99.9
100 or more	174	0.1	100.0
Total	160,775		

Table 8. Number and Size Classification of Farms by Departments, 1960 (3)

Department	Farm size: Less than 0.5 ha	0.5–3 ha	3–10 ha	10 or more ha
Capital	610	316	116	3
Concepcion	435	1,317	5,094	156
San Pedro	617	2,505	6,112	230
Cordillera	2,450	6,288	13,939	1,360
Guaira	3,030	3,152	7,278	442
Caaguazu	1,404	2,007	7,890	361
Caazapa	1,150	2,783	7,410	301
Itapua	1,727	2,386	10,912	1,653
Misiones	156	1,442	3,671	422
Paraguari	2,025	6,290	16,542	782
Alto Parana	97	504	744	27
Central	2,332	6,252	8,728	675
Neembucu	1,269	1,479	3,920	308
Amambay	32	74	1,527	444
Presidente Hayes	308	583	501	–
Boqueron	317	95	485	728
Olimpo	69	75	56	–
Total	18,026	27,548	94,925	7,892

Outside the minifundia area there also is much land available for cultivation. The government has title to about 600,000 ha in eastern Paraguay and about half of this is suitable for cultivation. Agrarian reform laws permit 10% of the land in private holdings of 10,000 ha or more to be expropriated for colonization. Not counting the Chaco, there probably is enough arable land to provide each farm (and ranch) unit with at least 55 ha (18). This certainly should be adequate to support farming at a high level of technology.

The very large increase in wheat production between 1967 and 1969 (table 4) illustrates the ability of at least some Paraguayan farmers to move into commercial production when adequate incentives are provided. As a part of the GOP efforts to reduce wheat imports, special incentives were established to encourage producers to cultivate more than 100 ha of wheat. These incentives were primarily loans to purchase land and equipment on a large scale. As a result, wheat hectarage nearly quadrupled in two years.

Mechanized farming, however, is still limited to less than 5% of the total land cultivated. Only 9% of the farmers presently have 10 ha or more in their farm unit (table 7).

SOIL FERTILITY PRACTICES AND USE OF LIME AND FERTILIZER

Given the small size of the land holdings being farmed by the majority of Paraguayan farmers, it is not surprising that fertilizer consumption has been historically low. Most of these small-scale farmers operate on a subsistence basis and meet their needs with a minimum cash input into their land. However, it is interesting to note that a relatively large number of farmers in Paraguay have employed soil fertility amendments to maintain production. Most of the small-scale farmers have relied on organic fertilizers, such as animal manures, but some have also used inorganic fertilizers (table 9). Thus, inorganic fertilizers, while obviously used in very small amounts, are not necessarily an untried input for small farmers as is the case in many developing countries.

The consumption of chemical fertilizers in Paraguay is most directly related to activities of the farmers with relatively large land holdings. As shown in table 10, there was a very rapid increase in imports for the years 1968 and 1969; this coincides with the initiation of the wheat-soybean program. While there may have been some carry-over of the 1969 fertilizer into the 1970 program, there nevertheless was a sharp increase over the previous year. The number of farmers involved in this increase in fertilizer consumption was relatively small, perhaps on the order of 100 or so. Most of this fertilizer was reportedly applied according to recommendations established by the wheat program.

The importation of fertilizer nutrients for the years 1960 to 1966 are given in table 11. The balance of nutrients during this period shows that phosphorus was the lowest of the three. However, in the period 1967 to 1969 the wheat program's recommendation swung to fertilizer formulas in which phosphorus predominated. The predominant fertilizer grades imported during the three-year rapid growth period were 46-0-0, 18-46-0, 0-46-0, and 0-0-60.

Table 9. Number of Farmers Reporting Fertilizer Use by Size of Land Holding, 1956 (4)

Farm size	Number of farmers reporting	Number of farmers using fertilizer	
		Organic	Inorganic
Total ha	149,614	14,492	2,575
Less than 0.5	1,593	195	22
0.5-0.9	4,829	429	61
1.0-1.9	17,549	1,458	234
2-2.9	17,793	1,619	287
3-3.9	15,253	1,467	256
4-4.9	11,697	1,262	210
5-7.4	24,404	2,636	439
7.5-9.9	10,545	1,144	190
10-19.9	25,192	2,321	492
20-49.9	12,982	1,131	245
50-99.9	2,837	343	62
100-199.9	1,568	175	29
200-499.9	1,234	132	25
500-1,000	589	62	7
1,000-2,500	687	58	9
2,500-5,000	328	23	2
5,000-10,000	259	11	2
10,000-20,000	130	11	1
20,000 or more	145	15	2

Table 10. Importation of Chemical Fertilizers (51)

Year	Fertilizer volume	Value	
	mt	US$	G1,000
1962	835	52,524	6,618
1963	1,114	87,480	11,022
1964	1,311	115,209	14,516
1965	1,343	108,846	13,715
1966	775	63,354	7,983
1967	985	80,540	10,148
1968	3,509	307,360	38,737
1969*	7,353	538,452	67,845

*Up to September.

Table 11. Importation of Fertilizer Nutrients, 1960-1966 (13)

Year	Plant nutrient		
	N	P_2O_5	K_2O
		mt	
1960	16.9	10.0	29.1
1961	61.1	16.3	31.4
1962	126.0	59.4	80.4
1963	148.3	98.3	142.6
1964	206.3	148.3	239.7
1965	106.8	80.0	112.8
1966	104.3	83.2	111.7

The soil testing laboratory at the FAV has been operating for 5 years under the general philosophy and methodology of the ISFE with international headquarters in Raleigh, North Carolina. The local soil testing program has experienced difficulties in working at its potential because two soils technicians were away taking advanced training in the United States. Also, the program has not had the technical assistance of a regional director in the area as has been the case of most other Latin American countries cooperating with the ISFE. Correlation research and program development with regard to fertilizer recommendations have only recently been initiated, largely as a result of the present fertilizer study. Laboratory equipment has been recently improved with the installation of new equipment and apparatus for rapid analyses, a contribution of the ISFE. An accelerated plan for program development has been prepared, including a research program which is outlined in section VI of this report.

Employees at the soil testing laboratory make specific fertilizer recommendations for various crops based on analytical tests. Formal fertilizer guides have not yet been developed in terms of rates of application, due to the uncertainty as to levels of fertilizer response to expect and yield goals which are possible with the varieties under cultivation. However when the soil tests are low for both phosphorus and potassium, the current recommendations employ ratios in which phosphate predominates (1-2-1 and 2-3-2) for wheat, corn, and rice. In the case of soybeans and cotton, the ratios are 1-4-4 and 2-3-3, respectively. Recommendations for tobacco, sugarcane, and vegetables employ higher potash ratios, usually 1-2-3, 3-2-4, and 2-2-3, respectively. A typical set of recommendations is given in table 12. The low rates recommended reflect the high price of fertilizer in Paraguay. For fields where soil tests are medium or high in phosphorus and/or potassium, recommendations of these nutrients are cut in half or deleted altogether, depending on local conditions.

Lime recommendations are a relatively new part of the soil testing program. The lack of an economically priced limestone available to the farmer has made it all but impossible to follow a lime recommendation anyway. Quality control in agricultural limestone is also lacking. Pending further conclusive research regarding an appropriate soil test to predict lime requirements, a lime recommendation is being initiated which is based on the amount of exchangeable aluminum in the soil. For each 1.0 meq Al^{+3}/100 g soil, the lime recommendation is 1.5 mt/ha of limestone.

Table 12. Typical Fertilizer Recommendations for 1970 (34)

Crop	Recommended rate of application		
	N	P_2O_5	K_2O
		kg/ha	
Wheat	30-40	60	20-30
Soybeans	10-15	40	40
Corn	30	45	30
Sugarcane	60	30	80
Cotton	20-30	40	40
Tobacco	30-40	40	60
Vegetables	30-40	30-40	40-60
Rice	30	45	30

Increased alfalfa production could reduce dairy imports.

CROP RESPONSE TO LIME AND FERTILIZER

Although most of the soils of eastern Paraguay are generally quite acid, experiments with lime have been generally lacking. Some lime has been applied on two experimental stations in preliminary trials (Caacupe and San Lorenzo FAV) but response data have not been reported to date. The experimental stations at the FAV and Caacupe are, however, located on soils with a natural pH of 5.5 or above; thus, tests with limestone might not be expected to give yield responses in wheat. The sub-experimental station, CREA, at San Juan Bautista, currently has an experiment in progress with alfalfa which indicates that a positive response to lime will be obtained. Soils at this station have a pH of about 5.2 and about 0.5 meq Al^{+3}/100 g soil. The soils on the experimental station at Capitan Miranda are slightly more acid and soils in the Pedro Juan Caballero and Puerto Presidente Stroessner area are very acid in spots. Experiments in these areas have given some rather abnormal fertilizer responses; some wheat plantings in both areas even failed to germinate because of the acidity.

Tall wheats are not suitable for heavy rates of nitrogen.

Fertilizer experiments have been carried out by the MinAg with wheat, sugarcane, corn, and tobacco over the past decade. Very few of the experiments have enough analytical data available on the soils used in the experiments for a rational interpretation of yield responses. Eight experiments were carried out in 1967, but of these only four gave any significant response to phosphorus. Two of the other experiments were conducted on sites that were probably not deficient in phosphorus (Caacupe Experimental Station and Friesland) and the other two experiments were located on sites that probably were acid enough to limit yield response (Capitan Miranda and Pedro Juan Caballero). Thirteen treatments were replicated five times in these experiments. In 1968 the same experimental design was employed at another eight locations; only one experiment showed phosphorus response (San Ignacio). A brief analysis of the other experiments suggests that two sites were again probably too acid (Capitan Miranda and Pedro Juan Caballero) and three more likely were conducted on soils well supplied with phosphorus (Caacupe Experiment Station, Friesland, and Coronel Oviedo). Yields were so low at the other two experiments (Arroyos y Esteros and FAV Experiment Station at San Lorenzo) that phosphorus probably was not able to provide a response large enough to be measured. Detailed soil analyses of many of these tests are not available so that precise evaluations and correlations cannot be made. The five experiments showing phosphorus response in the 1967 and 1968 trials are summarized in table 13. The response to fertilizer in these experiments shows a pattern almost identical to that obtained with similar experiments on comparable soils throughout the world: (1) no response to nitrogen in the absence of phosphorus, (2) no response to NK in the absence of phosphorus, (3) no response to potassium at this yield level (potassium response in soils classed as medium in available K usually is not observed at yields below 1,000 kg/ha), and (4) a physical (but not necessarily economical) response to P_2O_5 up to 120 kg/ha.

Several factors contributed to the outcome of these experimental results. First, the varieties employed during the 1967 and 1968 experiments were tall growing varieties which lodged considerably at higher fertilization rates.

Table 13. Summary of Fertilizer Experiments with Wheat for Fields Showing a Response to Phosphorus; Ministry of Agriculture Experiments 1967-1969

Fertilizer treatment (N-P_2O_5-K_2O)	Yield 1967	Yield 1968	Fertilizer treatment (N-P_2O_5-K_2O)	Yield 1969
		kg/ha		
20-0-0	943	1,690	20-30-0	1,829
40-0-0	897	1,373	40-60-0	1,942
60-0-0	968	1,383	60-90-0	2,045
20-40-0	1,505	2,357	20-30-20	1,886
40-80-0	1,535	2,430	40-60-20	2,011
60-120-0	1,599	2,520	60-90-20	1,962
20-0-20	1,016	1,533	60-90-40	1,960
40-0-40	914	1,553	0-0-0	1,487
60-0-60	952	1,540		
20-40-20	1,382	2,313		
40-80-40	1,426	2,483		
60-120-60	1,597	2,490		
0-0-0	972	1,527		

These varieties were not necessarily the most suitable varieties; variety trials conducted in the same areas usually showed that other varieties yielded more than those employed for the fertility experiments. Finally, the use of a standardized design, with uniform application rates, did not permit a proper evaluation of the interactions between nutrients nor of the optimum application level of the individual nutrients.

Five experiments were conducted by the MinAg in 1969. Results are included in table 13 to point out several features of importance in wheat fertilization.

First, these experiments gave high yields without fertilizer (0-0-0 treatment) indicating that fertility levels were higher than normally expected for farmer fields. A good response was obtained at low application rates but the yield increase fell off rapidly at higher rates. Since the varieties used for three of the experiments were tall and lodging occurred, this could account for some of the poor response at the high rate. Further, it is likely that the upper limit of yield capacity was being approached by the tall varieties. The best yield (2,678 kg/ha) was obtained with variety 214 at the Caacupe Experimental Station and the yield response due to fertilizer was 935 kg/ha. The experiment at San Juan Bautista, CREA, netted the biggest fertilizer response (1,219 kg/ha) while two experiments gave only small responses to fertilizer application.

The experiments carried out by the MinAg were well done, as measured by the coefficients of variation which were quite low. Several observations can be summarized from the experiments. First, soil samples were taken from most experiments but the samples were not stored in a permanent research file for future checking. Many of the results from the original analysis are no longer available. This seriously limits present interpretation and correlation with soil tests. Second sites of experiments were not chosen on the basis of soil analysis so as to give a representative range of soil fertility conditions and the fertilizer responses which might be expected. Many of the soils on the experimental stations have been fertilized for a number of years and the fertilizer response on these soils is very different from most farmer fields. Potassium response data are particularly misleading, since virtually none of the experiments were carried out on low potassium soils. Yet, 66% of the soil samples in the northern zone, 44% in the central zone, and 43% in the southern zone were deficient in potassium (table 2). Finally, the experimental designs do not permit a clear picture of the specific nutrients responsible for the yield increases; calculation of the most economical ratios or formulas of fertilizer is difficult. In order to make better use of the good experimental capability of the various technicians of the MinAg, a number of specific suggestions are given in section VI. The fertilizer and lime trials carried out by the FAO program are extensive enough to cover a fairly complete range of soil fertility conditions. These results were not available for this report but the information gained from the trials can be incorporated into the soil testing programs to improve considerably the calibration of soil test recommendations.

GOP PROGRAMS AND POLICIES

In 1968 the National Council of Economic Coordination drew up a 5-year plan for social and economic development in Paraguay. Guidelines were established for the medium-term policies and some of the long-term goals of the country were examined. An important part of the overall planning revolved around a strategy of "growing toward the outside," essentially an increase in production for exportation. A complementary component of the plan involved a simultaneous substitution for importation of products of agricultural origin. Further goals included emphasis on the production of raw material of agricultural origin and of greater and more efficient utilization of natural resources, incorporating new lands into the productive process, and carrying forward a more rational and intensive use of soils already under cultivation.

Products selected for immediate emphasis included wheat, milk, oilseeds, potatoes, and onions for the import substitution program. The policies established by the National Wheat Council carried enough strength to make an impact of considerable significance. Probably one of the biggest factors permitting the rapid expansion in wheat production to date has been the input of new sources of external financing and incentive programs which provided

Bringing new land into cultivation frequently requires destroying innumerable termite mounds and correcting their aftermath toxicity.

broad-range credit to farmers cultivating more than 100 ha of wheat. This credit resulted in a substantial increase in mechanized wheat farming, with an additional benefit being gained by double-cropping with soybeans (tables 4 and 5). Wheat production in the country has improved the level of self-sufficiency from roughly 10% to 40% from 1967 to 1970 and soybean production has approached essentially a self-sufficiency level.

When compared to the strides made with wheat and soybeans, the progress made with the import substitution of potatoes and onions is somewhat dwarfed. Nevertheless, self-sufficiency has been obtained in onions and some tentative plans for export to Brazil are being contemplated.

The national plan to improve export participation has been reasonably successful with tobacco, largely as a result of efforts made by the National Tobacco Program. Emphasis has been put into improving varieties and cultural practices, including the promotion of techniques designed to improve quality of tobacco so as to better compete in the external market. Goals of the program (21,000 mt by 1973) already have been exceeded but quality changes may be more difficult to bring about. Cotton production was projected by the planning council at a level of 71,300 mt by 1973, a large increase considering the 40,000-mt production achieved in 1969. Furthermore, the human and financial resources available to conduct the program may be limited due to competition with other high priority programs, particularly wheat.

Price establishment is recognized in Paraguay as an important stabilizer in the drive to achieve a dynamic production. The GOP has set the price of wheat at ₲10.7/kg for the 1970 production, subject to certain quality standards. This price was established at a point well into the harvest period of the current crop, rather than being programmed in advance as a stimulus to producers. Price establishment on other crops may be added at such times as are necessary to meet the goals of the GOP but currently all other commodities operate on a free market.

Section IV

RESOURCES AND FACILITIES RELATIVE TO PRODUCTION, MARKETING, AND USE OF LIME AND FERTILIZER

EVALUATION OF PHOSPHATE AND LIMESTONE RESOURCES FOR AGRICULTURAL USE

This phase of the study describes the present status of indigenous mineral resources for agricultural use. A major limestone reserve in northern Paraguay near Vallemi and a suspected phosphate occurrence near Sapucai in east-central Paraguay were the initial considerations. When other parts of the TVA study began to show the extreme importance of limestone to fertilizer use and crop production, the mineral resources study was broadened to include all known limestone deposits.

Information used in the following descriptions of mineral resources was obtained from four sources: (1) short-term field reconnaissance of deposit sites, (2) regional geological surveys and maps prepared by Paraguayan agencies and the USGS, (3) consultations with the scientific staff associated with the Direccion de Recursos Minerales and the Instituto de Ciencias, Universidad Nacional de Asuncion, and (4) laboratory characterization studies of selected prospect samples carried out at the National Fertilizer Development Center of TVA. The assistance and free exchange of information by government agencies and private enterprise contributed substantially to this survey.

No complete geological survey of Paraguay exists to guide field exploration or to support the claims that it lacks mineral resources. Aside from Eckel's preliminary mapping of Paraguay's geological features (31), the only exploration guides currently available were four topographic quadrangle maps (M-1 to M-4), three quadrangle maps showing surface geology but without topographical controls (M-5 to M-7), and two photo reconnaissance charts (M-8 and M-9). All maps pertained only to the central region of eastern Paraguay. These maps are listed in table 14. Reproductions as a supplement to this report are available to qualified individuals upon request to TVA.

The objectives of this survey, therefore, were to describe regional settings and geological features of prospected sites, conduct a sampling program to furnish mineralogical descriptions, and to estimate their potential value to the agricultural program. The mineralogical data reported here should find further use in the geological mapping programs now under way by Paraguayan agencies.

Phosphate Occurrences

The region of major interest was the complex of igneous alkalic intrusives that Eckel (31) identified in south-central Paraguay on his geological map. Although interrelated, the intrusive structures form three regional groups. The main grouping is concentrated in a 700-km^2 region immediately south of Sapucai. A lesser grouping of small intrusive plugs occurs to the east near Villarrica. The third intrusive zone is an elongated complex that lies on an east-west axis roughly between Acahay and La Colmena. It is well recognized that apatite has a characteristic association with alkaline intrusives, particularly if carbonatites or pyroxenites occur in the intrusive zone (28).

Sapucai Complex—Morinigo and Penayo's survey of the major intrusives located about 4 km south of Sapucai clearly established their alkaline nature from characteristic rock types and mineral suites (54). Apatite was identified in petrographic thin-section examinations of rocks from the major intrusive zone, associated dikes, and basalt flows in the surrounding region and also in soil profiles derived by weathering. According to Penayo (47), all samples showed only accessory amounts of apatite (<5% by wt).

The geological features of the major intrusive complex are identified with topographical features in the Sapucai region in figure 5. The accompanying photograph gives an elevation view of the complex from a vantage point on the Cordillera de Los Altos north of Sapucai.

In spite of adverse field conditions due to local flooding, few access trails, and heavy vegetative cover, an extensive field survey of the region was started. The survey was discontinued when it became known that a comprehensive field survey covering the Sapucai intrusive complex had been conducted by Arribas during August-October 1969 under a United Nations grant (19). About 170 rock samples were collected in the survey and are undergoing detailed laboratory examinations in Brazil and Spain. A final report has not been prepared.

Intrusive complex near Sapucai

Reserve samples from many of these sampling stations were retained in collections at the Universidad Nacional de Asuncion. Portions of these were made available for use, together with a record of sample stations and a preliminary geological map. A composite diagram of their field map with locations of samples discussed in this report is shown in figure A-1 in the appendix.

Field inspection, as well as an examination of the comprehensive Arribas collection, did not reveal rocks of the carbonatite or pyroxenite types; neither did inspection with a hand lens reveal visible concentrations of apatite. Apatite, if present, must be fine-grained and present in no more than accessory amounts, judging from recognizable components of the mineral matrix.

The TVA laboratory study of samples from the Arribas collection and other sources was restricted, therefore, to chemical analyses of P_2O_5 content to confirm the seemingly low concentrations of apatite in the various rock types. These analytical results are in table 15 and they confirm that apatite concentrations in all rock types are too low to have any economic significance. This finding precluded the need for additional petrographic characterization of apatite compositions or rock types at this time; investigations of this nature will be included in the final Arribas report.

The low concentrations and fine-grained nature of the apatite in host rocks very likely preclude any placer concentrates of economic importance in contiguous alluvial deposits or soil profiles. Soil samples from two areas (P-7S and P-8S), for example, contained about 2,500 ppm total P_2O_5, indicating little, if any, enrichment in relation to parent rock material in the immediate area.

There is no evidence at the present time, therefore, that favorable carbonatite formations or economical concentrations of apatite exist in the Sapucai complex of intrusives. The current status of geological mapping in this region, however, offers no realistic basis for abandoning a further search. It is quite possible that the area may contain undetected apatite zones. Occurrences can easily be missed in "broad-brush" geological reconnaissance conducted

Table 14. Paraguayan Maps and Charts Used in Surveying and Describing Mineral Sites

Reference No.	Description
	Quadrangle Topographical Maps
M-1	Hoja 5569-I, Serie H741. San Jose. Carta Nacional, Paraguay, Primera Edicion-I.G.M. 1:50,000; 15' x 15'. Instituto Geografico Militar Paraguay and Servicio Geodesico Interamericano.
M-2	Hoja 5569-II, Serie H741. Coronel Martinez. Carta Nacional, Paraguay, Primera Edicion-I.G.M. 1:50,000; 15' x 15'. Instituto Geographica Militar Paraguay and Servicio Geodesico Interamericano.
M-3	Hoja 5569-III, Serie H741. La Colmena. Carta Nacional, Paraguay, Primera Edicion-I.G.M. 1:50,000; 15' x 15'. Instituto Geographica Militar Paraguay and Servicio Geodesico Interamericano.
M-4	Hoja 5569-IV, Serie H741. Sapucai. Carta Nacional, Paraguay, Primera Edicion-I.G.M. 1:50,000; 15' x 15'. Instituto Geographica Militar Paraguay and Servicio Geodesico Interamericano.
	Surface Geological Maps
M-5	No. 11, Cuadricula 40. 1966. Ita. 1:200,000; 1° x 1°. Departamento de Geologia, Direccion de Recursos Minerales, M.O.P. y C., Republica de Paraguay.
M-6	No. 13, Cuadricula 41. 1966. Coronel Oviedo. 1:200,000; 1° x 1°. Departamento de Geologia, Direccion de Recursos Minerales, M.O.P. y C., Republica del Paraguay.
M-7	Esquema Geologico del Area de Sapucai. 1:50,000. Antonio Arribas (38).
	Photo Reconnaissance Charts
M-8	Sheet 5669, Series HO41. 1966 Villarrica. Edition 1-AMS, Paraguay Photomaps. 1:100,000. Army Map Service, Corps of Engineers, U.S. Army, Washington, D. C.
M-9	Sheet 5670, Series HO41. 1966 Coronel Oviedo. Edition 1-AMS, Paraguay Photomaps. 1:100,000. Army Map Service, Corps of Engineers, U.S. Army, Washington, D.C.

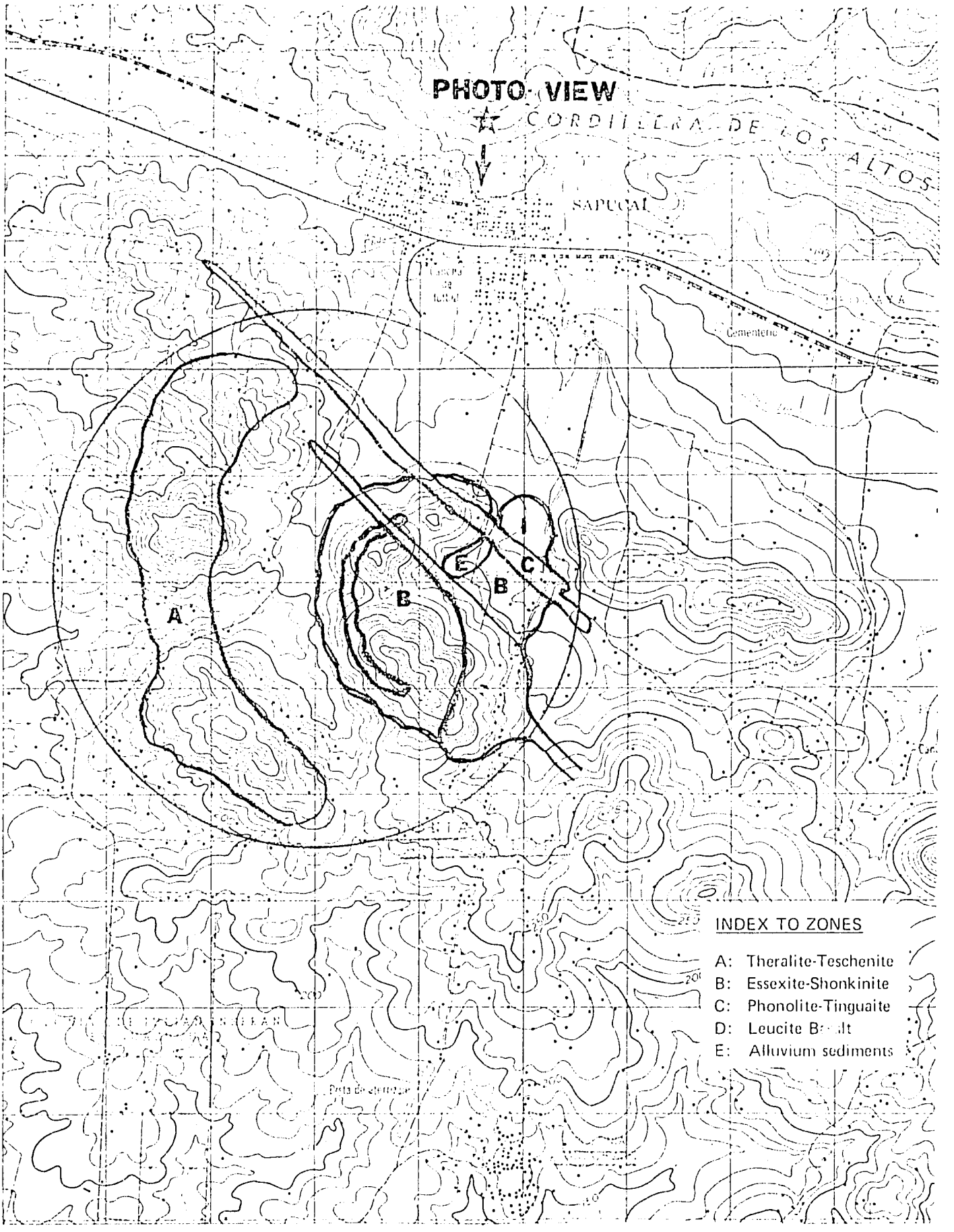


Figure 5. Correlation of geological structures in major Sapucai intrusives with topographic detail

Table 15. Phosphate Content of Sapucai Intrusive Rock Samples

Rock type	Sample[a] No.	P_2O_5[b]	Sample[a] No.	P_2O_5[b]
		%		%
Leucite, basalt, sodalite, analcimite, leucitite, limburgite	10	0.70	82	0.56
	12	.15	84	.39
	25	.37	89	.38
	27	.52	119	.71
	33	.41	125	.29
	38	.66	127	.43
	48	.06	165	.45
	71	.75	167	.58
	81	.63		
Essexite-shonkinite	1	.86	156	.26
	67	.51	158	.10
	68	.48		
	69	.20	new samples	
	70	.48	P-7[c]	.51
	152	.61	P-7S	.27
	153	.14	P-8[d]	.07
	155	.58	P-8S	.25
Phonolite-tinguaite	3	.42	150	.23
	4	.06	157	.78
	66	.69	162	.53
	86	.09		
Diabase, Lamprophyre, microsienite	18-19	.71	72	.62
	24	.70	79	.46
	46	.51	121	.79
Triassic sandstone	29	.07		
Theralite-teschenite	73	.39	77	.65
	76	.38	78	.51

[a]Arribas collection; sample stations shown in figure A-1.
[b]Approximate apatite content = % P_2O_5 x 2.44.
[c]Corresponds to Penayo sample station No. 3; "S" designates soil sample.
[d]Corresponds to Arribas sample No. 158; "S" designates soil sample.

along easy access routes because such occurrences in alkalic intrusives frequently have very small surface delineations. Only a detailed geological mapping of topographical features by systematic cross-country traverses will resolve the matter of phosphate resources in the Sapucai region.

Villarrica Intrusive Complex—Representative intrusive plugs in the Villarrica group were inspected to determine rock types and to examine fresh samples for evidence of apatite. In a few instances where the rock was too fine-grained to make an appraisal, samples were collected for chemical determinations of P_2O_5 content.

The few intrusive formations examined showed no visible indication of apatite. Samples collected at the intrusive plug located about 12 km south of Coronel Oviedo and about 1.2 km east of the highway had P_2O_5 contents no higher than 0.86%. Similarly, samples of an intrusive plug located about 700 m northwest of Mbocayaty (near Villarrica), which Eckel (28) describes as mostly shonkinite with some nepheline syenite, had P_2O_5 values no higher than 0.45%. Some, but not all, of the dome features visible in the area are located on the regional geology map (M-6) and have been sampled previously (11), but no apatite occurrences were reported.

Further field mapping and sampling will be necessary before the region can be dismissed as a potential source of phosphate; however, present indications are not encouraging.

Acahay-La Colmena Region—The area about 20 km east of Acahay and south of La Colmena contains a large, unmapped complex that probably is intrusive and that is only crudely defined on Eckel's 1959 survey map (31). Efforts to survey this complex were cancelled due to extensive regional flooding and closure of the only access route. No map records or eyewitness accounts of geological structures, rock types, or mineral compositions were available. This complex, like Sapucai, merits equal consideration as a potential source of phosphate and should be examined at the earliest opportunity—at least to confirm the suspected intrusive nature.

Limpio Region—Reports of a suspected phosphate occurrence southwest of Limpio (about 12 km north of Asuncion) led to a brief reconnaissance of the area which contained quarry exposures of an intrusive olivine basalt that showed extensive weathering. This particular formation apparently has not been described (10), nor does it appear on the geological map of the region (M-5).

Positive chemical tests for phosphate were obtained on both weathered and unweathered rock in a field test using an improvised reagent mixture of nitric acid and ammonium molybdate. Apatite could not be identified with a hand lens in the fine-grained basalt. Samples of weathered and unweathered material were collected for laboratory analysis. Two composite samples of fresh unweathered black basalt taken 3-4 m below the surface from different locations along the quarry face had P_2O_5 contents of 0.88% and 0.87%, corresponding to apatite concentrations of just over 2%. Two samples from the weathered subsurface zone had slightly lower P_2O_5 contents of 0.53% and 0.76%. Samples of highly-weathered, disintegrated surface rock contained only 0.25% and 0.39% P_2O_5, which is an indication of a gradual depletion of phosphate associated with the weathering process (supergene enrichment).

The rock does not contain concentrations of phosphate high enough for economical development for fertilizer use;

neither would it appear to have any value in crushed form for direct application as a phosphate supplement. The P_2O_5 in igneous apatite compositions is virtually unavailable to crops in most soils, regardless of its mesh size. Furthermore, the ratio of $F:P_2O_5$ in igneous apatites such as this precludes a consideration of its use as an animal feed supplement.

Sedimentary Phosphate The finding of sedimentary phosphatic limestones (described below in the section on limestone occurrences) of Triassic or Lower Permian age in the Caaguazu area indicates a possible occurrence of sedimentary apatites. The oolitic texture, the distinct depositional layers of a siliceous, phosphatic, or fossiliferous character, and the association of cherty (opal) silica as interstitial cement and intercalations imply deposition under marine conditions. If so, the phosphate content of the limestone can be expected to vary, depending on localized conditions of deposition and the amount of soluble phosphate available to react with the precipitated carbonate. While the presently identified occurrences contain too little phosphate to be of any economic importance, they point to the possible occurrence of phosphate-enriched limestones in other areas of this stratigraphic unit.

Phosphatic limestones generally are regarded as problem ores for manufacturing fertilizers. Nevertheless, they are especially well suited for direct application without chemical processing because their apatite component has a characteristically high citrate solubility and availability to plants. Thus, the discovery of limestone reserves with submarginal phosphate contents would still find ready application in an agricultural program as a combination liming agent and phosphate supplement.

Limestone Occurrences

Early recognition by the TVA team of the need for an agricultural liming program prompted an extension of the mineral survey to establish the types and amounts of limestone reserves. The search was concentrated mainly in the region east of Rio Paraguay, where an estimated 700,000 mt of agricultural limestone will be required during the next 10 years.

The present evaluation of limestone reserves for agriculture is based on (1) a review of available scientific, GOP, and private reports on limestone deposits; (2) field inspection of quarry sites and suspected deposits to collect samples and conduct interviews; and (3) geological descriptions, maps, and field sketches of limestone exposures. The following section describes mineral and chemical compositions of representative samples collected at each deposit and assesses grade and reserves.

Limestone characterizations were made in the laboratories of the National Fertilizer Development Center of TVA. X-ray diffraction methods were used to establish the structural types of carbonate minerals. The noncarbonate mineral groups were isolated by chemical methods and identified by petrographic examination. Chemical analyses of important constituents were obtained to calculate a model distribution of mineral components for each limestone. Limestone compositions are expressed in the form of calculated mineral compositions; basic chemical and mineral data appear in appendix tables A-4 and A-5 and show close agreement.

Northern Paraguay Deposits At least three established quarry sites occur on the western perimeter of a well-defined carbonate structure in northern Paraguay and neighboring Brazil (9, 31) having a diameter of about 125 km. These quarries occur in outcrops along the Rio Paraguay, as shown in figure 6.

a. Itapucumi. Two small prospect quarries in an outcrop about 150 m from the river bank expose a weathered bituminous calcitic stone (Site No. 1). The major quarry is situated a few kilometers to the west of the Rio Paraguay (Site No. 2). Its precise location and geographical setting is well described (9). Currently, lump limestone is quarried

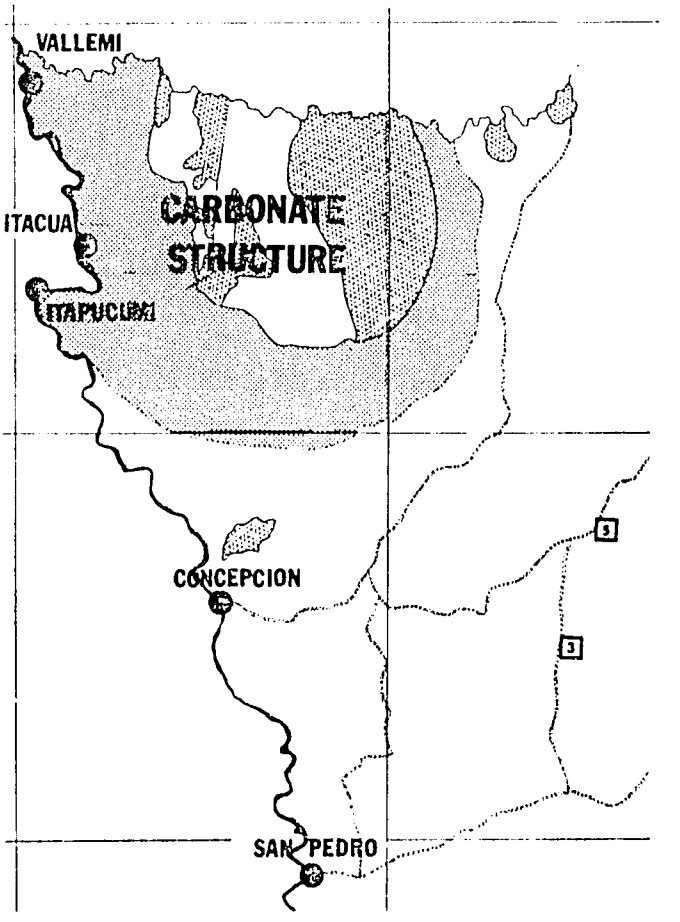


Figure 6. Geographical location of major carbonate structure in northern Paraguay

Current mining methods limit production.

manually, hauled by rail push cart to a riverside kiln, and processed into mortar lime.

Both sites were sampled. The samples from Site 1 represent a composite of mining-grade dark, fine-grained limestone (No. 10) and a composite of weathered zones penetrated by the alluvial overburden (No. 11). Material from this quarry probably would be satisfactory for agricultural stone or mortar use but appears too siliceous for blast-furnace grades (table 16).

The samples collected at the major quarry (figure 7) from mined stockpiles along the quarry face have compositions indicating a uniformly high-grade calcitic stone (table 16). Silica contents appear to be substantially below specification limits for blast-furnace use. A composite of fracture fillings (sample CC) collected along the quarry face (stations 12 through 15) show this material to be clear calcite, as well as the source of the CaF_2 detected in sample 15. No siliceous fracture fillings were found in any of the hand specimens.

This quarry represents a high-grade reserve of calcitic limestone for multipurpose use. By stripping overburden, much silica contamination could be avoided and the fine-sized material that is rejected for industrial use could become a desirable high-grade agricultural stone.

b. Itacua. The only active quarry penetrates a river bluff outcrop about 100 m from the shoreline. The limestone is a dark, fine-grained calcitic type similar to Site 1 at Itapucumi. Cross fractures are numerous and appear to be filled with clear calcite. Overburden consists of a friable, white, clay-like material of variable depth up to about 3 m.

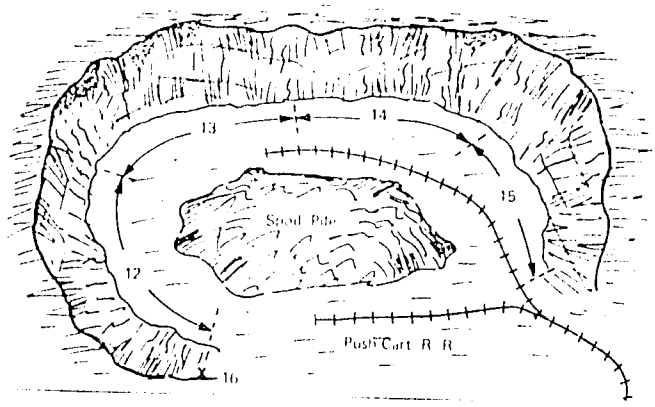


Figure 7. Itapucumi quarry showing sample stations at approximately 50-m intervals along exposure.

Table 16. Mineral Composition of Itapucumi Limestone

Mineral phases	Sample Nos. Site 1: 10	11	Site 2: Main quarry 12	13	14	15	16	CC
	Wt %							
Calcite	93.9	87.1	89.6	98.4	98.5	95.7	98.2	99.0
Dolomite	0.9	0.9	9.1	0.9	0.5	1.8	0.9	0.5
Quartz	2.5	6.6	0.9	0.2	0.2	0.7	0.6[a]	0.1
Micas + illite	1.6	3.8		0.3	< 0.1	0.7	0.1[a]	
Goethite-limonite		[b]	0.1	0.2	< 0.1	0.2	0.1	
Fluorite, CaF_2						0.7		0.3
Carbonaceous solids	0.5	0.6						
Moisture (105° C)	0.1	0.3	0.1	0.1	< 0.1	< 0.1	< 0.1	< 0.1
Organics + H_2O^+	0	(0.3)[c]	0	0	0	0	0	0
Total	99.5	99.3[b]	99.8	100.1	99.3	99.8	99.9	99.[illegible]

[a]The analytical value for SiO_2 (0.2%) appears to be too low by a factor of three; the actual SiO_2 content should be between 0.5%–1.0%.
[b]Remainder includes limonite lost in extraction process to recover the noncarbonate mineral group.
[c]Accounted for by carbonaceous solids listed above.

Table 17. Mineral Composition of Itacua Limestone

Mineral phases	Sample Nos. 17	18	19
		Wt %	
Calcite	94.6	99.3	88.7
Quartz	2.8	0.5	2.7
Opal (gel) + chalcedony			2.7
Mica group	1.2	0.1	2.7
Illitic clay			2.7
Moisture (105° C)	<0.1	<0.1	0.8
Organics + H_2O^+	1.1	0	(0.5)[a]
Total	99.7	99.9	100.3

[a]Excluded from summation since it represents dehydration loss from silica gel, micas, and clay fraction.

Samples were collected to represent a composite of quarried stone (No. 17), a composite of fracture fillings (No. 18), and a composite of the chalky, weathered overburden (No. 19). Mineral compositions are shown in table 17.

The limestone appears to be a slightly lower grade than Itapucumi stone, or lower grade than was reported for earlier prospect samples (22). Silica content appears to exceed specification limits for blast-furnace use. Fracture fillings are essentially pure calcite and not the source of silica contamination. An unsuspected finding was the rather high grade of the soft, chalky overburden. This material, which has a wide surface exposure on the broad plateau eastward from the quarry face, appears to be quite satisfactory for agricultural use with only a minimal requirement for further crushing and sizing.

c. Vallemi. Three quarries are located at the plant site of the Krupp-designed and government-operated cement plant, which is situated only a few kilometers eastward from the Rio Paraguay (figure 8). Two quarries supply calcitic limestone suitable for cement manufacture; the third quarry exposes a dolomitic limestone that is used only as a source of construction aggregate. A massive outcrop of brown-banded dolomite closely resembles the "bacon stone" described by Eckel (31) from a location to the east of Vallemi. The stone appeared to be uniform and high-grade over much of the exposed outcrop except for an expanding wedge of green-tinted limestone at the quarry base on the western edge of the pit. Numerous vertical and horizontal fractures filled with a white carbonate mineral occur throughout the banded dolomite. An overburden cap of alluvial soils appeared to average about 1-1.5 m in thickness.

Samples were collected to represent composites of quarried stone at three intervals along the face (Nos. 7, 8, 9), as well as a composite of fracture fillings (sample WS), and a composite taken exclusively from the green limestone base (sample GB). Mineral analyses are given in table 18.

The limestone, or "bacon stone," comprises a mixture of dolomite and calcite. It is somewhat lower in grade than Itapucumi or Itacua limestones and more siliceous. Fracture fillings usually consist of either dolomite or calcite but occasionally they are siliceous. The greenish-colored limestone that wedges into the quarry base from the west has a distinctly different mineral composition. It is mainly calcitic, with illitic clay (and mica) imparting the green coloration.

This limestone is well suited for agricultural use. Quarry operations are mechanized and on-site facilities exist for crushing and sizing at a capacity rate of 30 mt/hour.

Eastern Paraguay Deposits—a. Coronel Oviedo-Caaguazu Region. Reports of a limestone occurrence in this area prompted a field search. No description of deposits appears in the regional geological survey (11) and the area is mapped as upper Triassic sandstones (M-6).

Limestone outcrops were observed at several locations just north of Highway 7 near kilometer A167 (highway

Table 18. Mineral Composition of Vallemi Limestone

Mineral phases	Sample Nos. 7	8	9	WS	GB
			Wt %		
Dolomite	64.4	65.8	60.3	54.4	7.8
Calcite	21.4	22.3	28.0	25.9	82.1
Quartz	6.7	7.2	7.2	17.1	8.0
Mica mineral group	2.9	1.2	1.2	0.9	2.0[a]
Moisture (105° C)	<0.1	<0.1	<0.1	<0.1	<0.1
Organics + H_2O^+	0.4	nil	0.1	1.0	0.1
Total	95.8[b]	96.5[b]	96.8[b]	99.3	100.0

[a]Consists mainly of a green illitic clay.
[b]Remainder includes the colloidal limonite pigment in "bacon stone" and calcium sulfate that were lost during the extraction process to recover the noncarbonate mineral group.

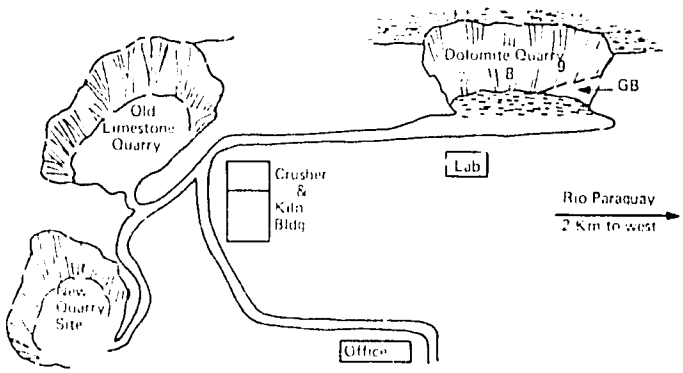


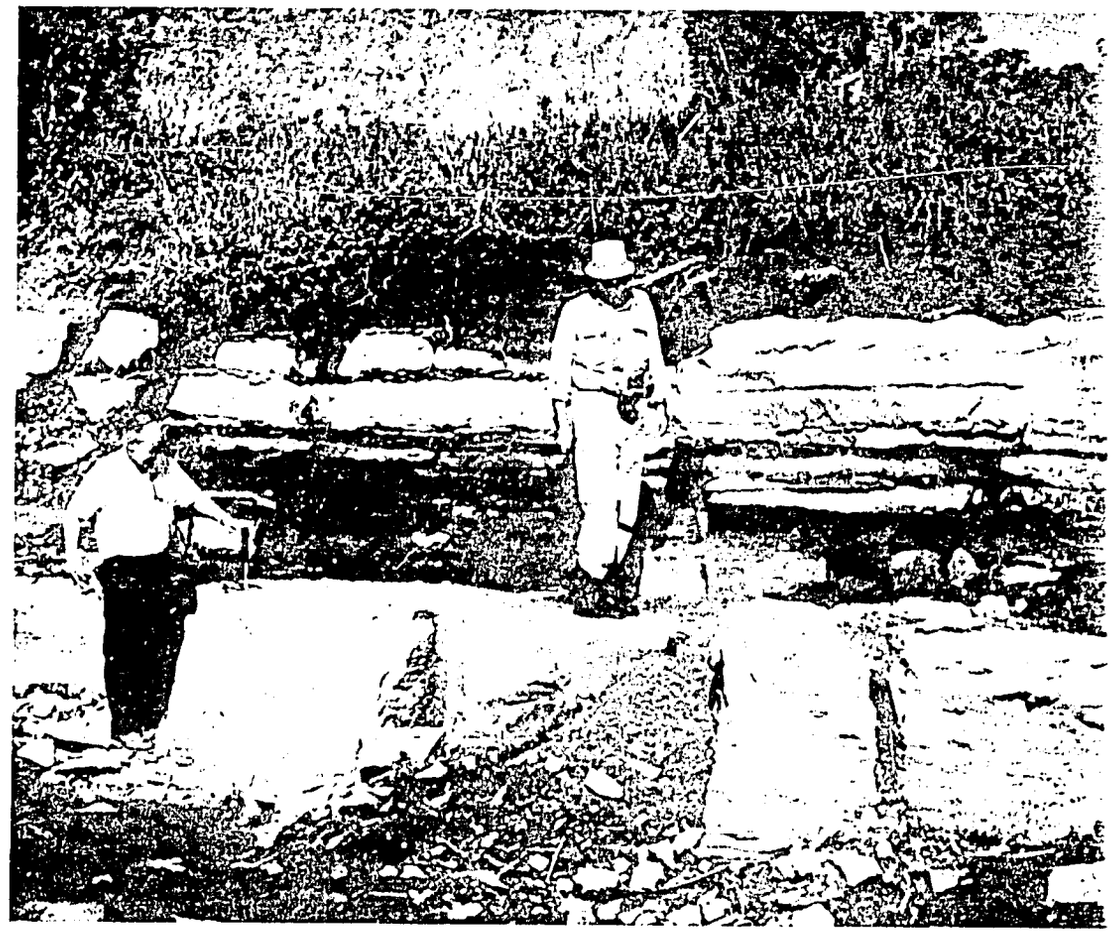
Figure 8. General layout of Vallemi limestone quarries showing sample stations along face of the dolomite exposure

Site 1 at Itapucumi

Site 2 at Itapucumi

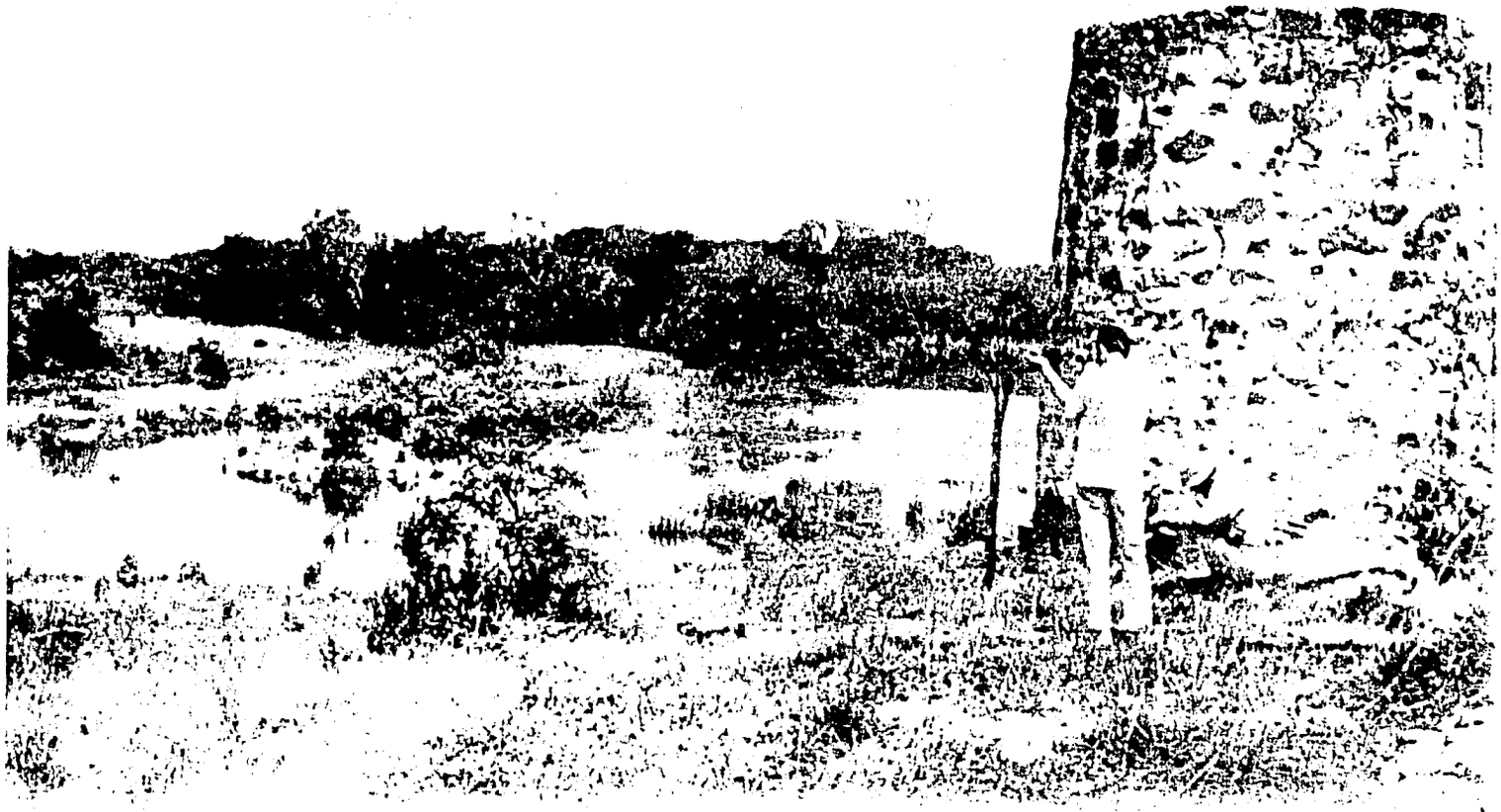
Dolomite quarry at Vallemi

"Bacon-stone" dolomite



Top stratum of limestone at Coronel Oviedo

Flooded dolomite quarry near Villa Florida



marker indicating distance to Asuncion) about 33 km east of Coronel Oviedo. Outcrops occur to the south of the highway but none were located on an east-west traverse along Highway 7 to define the extent of the deposit. The deposit supports three small lime kiln operations to the north of Highway 7 and one just south of the highway.

Quarry activities are restricted to the uppermost of three stratigraphic units. This is a thin (1-1.5 m), nearly horizontal stratum of pink oolitic calcite. The limestone tends to be siliceous owing to the presence of disseminated quartz grains, occluded elongate pods of cherty silica, and the occurrence in some locations of heavy silica cementation at the base of the unit.

The mineral compositions of samples collected from undisturbed outcrops and quarry stockpiles at the four quarry sites indicate a rather uniform composition for this uppermost unit (table 19).

Samples 20 and 21 were collected at the quarry site south of Highway 7 near kilometer A167; No. 20 is a composite of quarried kiln feed; No. 21 illustrates the reject grade of highly siliceous limestone that is sometimes associated with the pink oolitic stone. Samples 22, 23, and 24 represent composites from undisturbed outcrops and from quarried stockpiles located on the property of J. Segales. Sample 25 is a composite of the outcrops on the property of Desiderio Godoy and sample 26 is a composite taken from along the face of the quarry operated by Marcelo Casanas.

Samples from this stratigraphic unit have very similar textures and show highly uniform mineral distributions with respect to carbonate minerals, detrital quartz, and accessory minerals (notably feldspars). While somewhat lower in grade than limestones available in northern Paraguay, limestone in the Coronel Oviedo-Caaguazu area should be satisfactory for use as an agricultural liming agent.

The two principal commercial quarries are operated by SOFIN, SRL of Asuncion, and by Marcelo Casanas. Both operators sell limited quantities of calcined stone to meet a modest, but growing, market for agricultural lime in the Caaguazu area. Casanas employs additional preparation steps in which the burned lime is crushed and screened through a 100-mesh screen. His plant consists of improvised, small-scale equipment with a production capacity of about 1-2 mt/hour; the product is bagged in 50-kg units for sale. There are no crushing facilities in the area at present to prepare an agricultural grade of crushed raw limestone.

Two additional stratigraphic units of limestone were identified tentatively at lower elevations during a field reconnaissance guided by stereoscopic aerial photographs. A northerly traverse from Highway 7 at kilometer A168 for a distance of 1.5 km located outcrops of these units. A northwesterly penetration by vehicle along a logging trail for about 7 km from highway kilometer A170 failed to locate additional outcrops - mainly because the access route followed ridge elevations through dense ground cover.

Two operators had observed evidence for the second stratigraphic unit as exposed ledges and outcrops in creek beds below their quarries but no limestone had been quarried from it and its quality had not been determined.

This second limestone unit was relocated further north at about the same elevation as an extended outcrop in a hillside on Cirilo Benitez's farm. The third unit was exposed in creek beds to the north at the base of the hill; the creek bed elevation appeared to be 10-20 m below the second limestone unit.

These two lower stratigraphic units are also oolitic types but they are not like the uniformly textured, fine-grained, pink oolitic uppermost stratum. They comprise distinct depositional layers ranging from siliceous, phosphatic, fossiliferous, or iron-stained types to sandy layers of oolitic

Table 19. Mineral Composition of Coronel Oviedo-Caaguazu Limestone, Upper Stratum

Mineral phases	Sample Nos. 20	21	22	23	24	25	26
				Wt %			
Calcite	82.2	39.3	85.5	81.4	82.5	86.6	86.4
Dolomite	0.5	0.9	0.5	nil	2.6	3.2	0.9
Quartz (detrital)	11.9	2.8	9.8	13.0	10.5	6.4	7.8
Opal gel-chalcedony		50.9		0.4			
Feldspars (detrital)	0.9		1.4	0.9	0.8	0.5	1.8
Goethite-limonite	1.7	3.3[a]	1.4	1.8	1.5[a]	1.0	1.2
Clays (kaolinitic)	2.6		1.4	2.4	2.3	2.0	1.2
Moisture (105°C)	<0.1	0.2	<0.1	<0.1	<0.1	<0.1	<0.1
Organics + H_2O^+	0	(2.0)[b]	0	0	0	0	0.7
Total	99.9	99.4	100.0	99.9	100.2	99.7	100.0

[a]Limonite pseudomorphs after pyrite associated with goethite.
[b]Organics present but some water from silica gel included here so that total accounted for is probably no better than 99%.

calcite. Intercalations of chert and iron oxides in thin wavy bands also are present.

Qualitative field tests for phosphorus were positive for the middle and lower stratigraphic units but negative for the uppermost unit. Local enrichment of phosphate also was detected on old fractures and weathered surfaces, presumably due to precipitation of secondary apatite. Carbonate apatite (francolite) was identified by infrared spectroscopy in concentrates prepared by removing the calcite with 2% acetic acid. According to petrographic observations, the francolite occurs as thin cryptocrystalline hulls on many calcite oolites.

The discovery of sedimentary oolitic limestones that contain phosphate, fossiliferous zones, and intercalated as well as interstitial cherty silica (opal-chalcedony) strongly suggests deposition in a marine environment. The possibility exists, therefore, that more highly phosphatic zones may occur in the region due to local variations in the conditions under which chemical deposition occurred.

The samples taken of the depositional layers in outcrops of the middle stratigraphic unit on Benitez's farm are identified in figure 9. Individual samples consisted of one-pound composites of freshly exposed chunks. Sample 32 was a composite of the same stratigraphic unit collected at another outcrop face about 100 m to the east. The mineral compositions of samples from this limestone unit are shown in table 20. The mineral compositions shown in this tabulation offer further evidence that this formation is a distinct stratigraphic unit in relation to the pink limestone unit found at higher elevations. It contains much more silica and feldspars, but much less calcite and virtually no clays. It is further distinguished by its phosphatic nature, the presence of fossiliferous forms, and the abundance of chemically precipitated silica as an interstitial cement. Also,

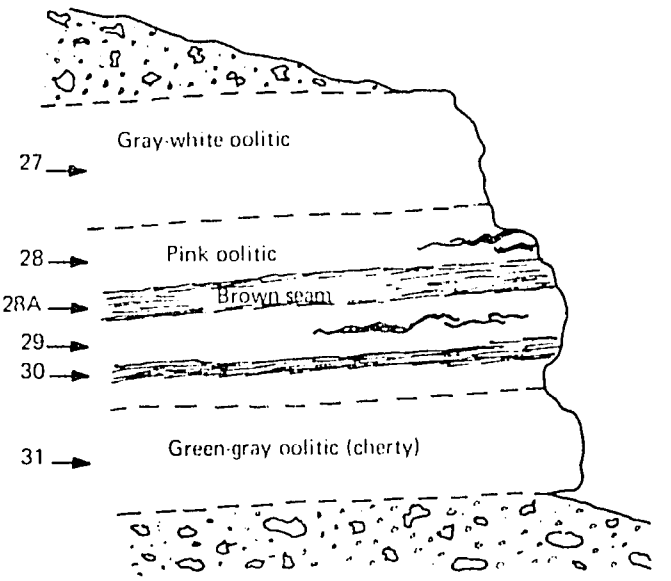


Figure 9. Sample composites from middle stratigraphic unit

the accessory minerals group in sample 27 is not present in any samples from the uppermost unit (samples 20-26).

A composite sample (No. 33) of the bottom stratum was collected at several points of exposure in the creek bed. Its grade and mineral composition resemble the middle unit but not the upper unit.

On the basis of only these few prospect samples, the middle and lower phosphatic units would appear to be of marginal grade for use as agricultural liming material. However, subsequent to the TVA survey, phosphatic limestone was discovered by a company geologist (SOFIN, SRL) at an undisclosed site farther to the north. This limestone (sample 40) is superior in grade and phosphate

Table 20. Mineral Composition of Coronel Oviedo-Caaguazu Limestone, Middle Stratum

Mineral phases	Sample Nos. 27	28	28A	29	30	31	32
				Wt %			
Calcite	41.3	47.2	60.5	45.4	53.7	45.0	77.0
Dolomite 1.4	nil	2.3	0.9	nil	0.5	0.5	
Quartz (detrital)	28.5	10.4	11.1	8.0	36.0	5.4	8.8
Opal gel-chalcedony	14.3	31.2	18.5	42.8	2.3	43.2	8.8
Feldspars (detrital)	11.4	7.8	3.7	1.6	2.3	4.3	3.3
Goethite-limonite		2.6	3.7	1.1	4.6	1.1	1.1
Accessory mineral Grp.	2.9[a]						
Carbonate apatite					0.5	0.2	0.3
Moisture (105° C)	0.2	0.3	0.2	0.3	0.5	0.2	0.1
Organics + H_2O^+	(0.2)[b]	(0.1)	0	0	0.4	(0.1)	0
Total	100.0	99.5	100.0	100.1	100.3	99.9	99.9

[a]Assorted detrital and heavy mineral types—mainly spinel, tourmaline, and opaque oxides.
[b]Represents H_2O from silica gel; omitted from total.

Table 21. Mineral Composition of Miscellaneous Limestones

Mineral phases	Sample Locations and Nos.		
	Coronel Oviedo-Caaguazu Lowest stratum 33	Colonia Independencia 34	Prospect sample (J.S.) Caaguazu area 40
Calcite	46.9	30.6	93.0
Dolomite	0.9	4.1	0.4
Quartz (detrital)	39.0	39.1	1.6
Opal gel-chalcedony	5.2		2.8
Feldspars (detrital)	5.2	6.5	0.3
Goethite-limonite	1.0	1.3	0.6
Clays (kaolinitic)		18.3	0.3
Accessory mineral Grp.	1.6[a]		
Carbonate apatite	0.5		1.0
Moisture (105° C)	0.2	0.9	0.2
Organic + H_2O^+	0	0	0
Total	100.5	100.8	100.2

[a]Spinel and a blood-red, isotropic, high-index mineral; not the same assortment as in No. 27.

content to any we examined from the Caaguazu area and should make an excellent liming agent (table 21).

The full extent and quality of this limestone deposit is poorly defined at present but holds promise for developing into a major reserve in the center of agricultural activity. Reported occurrences 10 km and 20 km north of Caaguazu (45) and 50 km north near San Joaquin (31), as well as 20 km south near Colonia Independencia (11), tend to define an elongate sedimentary limestone structure along this north-south axis.

No actual limestone outcrops were found in the area described near Colonia Independencia (11) but an abandoned quarry and kiln attest to a prior limestone occurrence. Samples collected from around the kiln and quarry-pit refuse—although calcitic—did not resemble closely the "margus" or black limestone of high organic matter content described for this area (11). Its chemical composition (sample 34) is also atypical. Rock refuse from a freshly cored, 7-m well about 1 km west of the abandoned quarry indicated penetration through a sequence of sedimentary sandstones only.

Further geological mapping probably should be concentrated in the region of the elongated prospect area to the north of Highway 7. This area, in addition to its limestone potential, may contain occurrences of marine sediments having economic values of apatitic phosphate. While the phosphate levels are likely to be submarginal for use as a fertilizer raw material, the phosphate content will add to the value of the agricultural limestone. The apatitic forms of phosphate usually associated with calcareous rocks have characteristically high values for citrate-soluble P_2O_5, which make them suitable for direct application.

b. Villa Florida. The reported occurrence of dolomitic limestone near Villa Florida (12) was investigated because of the need for a limestone source in the southern agricultural sector. A quarry site—temporarily abandoned due to local flooding—was located about 5 km west of Villa Florida on the northern bank of the Rio Tebicuary. The description of the quarry, according to the landowner, was a circular pit measuring about 15 m in diameter and 7 m in depth, indicating a maximum output of about 570 mt before flooding closed down production.

Samples were collected from stockpiles at the kiln; the landowner confirmed these as typical stone from this quarry. They consisted mainly of white, coarsely crystalline marble. Some stone of lower quality also was present; this material had a finer grain texture and comprised mixtures of carbonates, micaceous minerals, and an olive-green mineral. The mineral compositions of representative rock types are shown in table 22. Samples 2 and 3 represent composites of the coarsely crystalline white marble, which constituted the bulk of the stockpiled material; it is distinctly dolomitic and very high grade. Sample 5 also was coarsely crystalline, but contained abundant interstitial micaceous minerals.

Samples 1, 4, and 6 represent the lower-grade material, which amounted to about 10% of the stockpiled stone. Sample 4 represents a green-colored, medium-grain limestone consisting of an intimate mixture of carbonates, micaceous minerals, and accessory amounts of pink and opaque mineral grains. Sample 1 represents a low-grade, green, fine-grained limestone comprising carbonates embedded in a green mineral matrix. Sample 6 consisted of coarsely crystalline carbonates with a weathered or trans-

lucent milky appearance; some rock lumps contained distinct zones of unaltered clear carbonates and this translucent, milky material.

The mineralogical data clearly establishes the deposit as a metamorphic dolomite. The associated minerals—muscovite, black biotite, vermiculites, diopside, brucite, and SiO_2 as "vein quartz" are characteristic of a metamorphic mineral suite. The types of carbonates also reflect zonal variations during metamorphic alteration. In sample 1, for example, depletion of magnesia as diopside favored crystallization of a calcitic variety of carbonate. In sample 6, however, the mode of formation of calcite differs from both sample 1 and the more coarsely crystalline types (samples 2-5). Here, calcite and brucite occur in intimate association as pseudomorphs after coarse dolomite grains the result of alteration *in situ* due to local temperature-pressure conditions. The reaction mechanism, which has been identified in prior laboratory studies, can be represented as:

$$CaMg(CO_3)_2 \xrightarrow{\text{Thermal decomp.}} MgO + CaCO_3 \quad (I)$$

$$MgO + H_2O \longrightarrow Mg(OH)_2 \quad (II)$$

Numerous occurrences of quartzite and granitic exposures in the immediate region further identify a metamorphic structure. Considering the high quality of the dolomite and the southerly location of the deposit, the area merits further mapping at the earliest opportunity. Consideration should also be given to reclaiming the productive quarry by diking and draining. Development of this Villa Florida deposit would insure a balanced distribution from strategically located deposits in north, central, and southern Paraguay.

Limestone Reserves- At Itapucumi, the main quarry and test sites are estimated to cover an area of 420,000 m^2 and to have a depth of 17 m (9). This deposit, then, contains about 11 million mt of limestone. The geological setting and visible outcrops to the south favor a more extensive deposit than indicated by this single property survey.

Estimates of the reserves at Itacua are said to be in the Keller report (22). These estimates were made available to the TVA team in only general terms, i.e., that the limestone outcropped along the Rio Paraguay for tens of kilometers. Aerial reconnaissance confirmed that bluffs, presumed to be limestone, extended upriver for at least 20 km.

Reserves at the Vallemi site were calculated on the basis of the exposed quarry face and an assumed depth. These dimensions are approximately 150 m x 150 m for the quarry face and 35 m for the depth. A conservative estimate of the deposit is 200,000 mt of limestone.

A reliable estimate is available for only one sector of the Coronel Oviedo-Caaguazu deposit. It considers only the uppermost stratum on the property controlled by SOFIN, SRL. Assuming reasonable values for average thickness and lateral extent of the stratum, reserves total about 6.6 million mt. Of this total, about 12% (730,000 mt) is considered mineable at reasonable costs because of the problem of removing alluvial overburden. The reserves of this one deposit are just about equivalent to the projected needs for the entire nation for the next decade. The reserves in contiguous quarries, as well as in the newly discovered strata beneath the presently mined stratum, cannot be evaluated at this time. Obviously, the central Paraguay deposit has a very large total reserve and probably a very large mineable reserve too.

The prospect sites at Villarrica in east-central Paraguay

Table 22. Mineral Composition of Villa Florida Limestone

Mineral phases	Sample Nos. 1	2	3	4	5	6
			Wt %			
Dolomite		85.0	79.1	40.5	46.3	51.6
Magnesian calcite	33.9					
Calcite		12.5	17.7	33.6	34.3	32.9
Quartz (SiO_2)	19.2	1.5	0.4	1.3	0.9	0.3
Diopside, $CaMg(SiO_3)_2$	44.8					
Chlorites-vermiculite (acid Mg-silicates)			1.6	22.5	17.1	
Brucite, $Mg(OH)_2$						13.7
Accessory minerals (black biotite, ruby spinel, etc.)				1.3		
Moisture (105° C)	0.7	0.1	0.1	0.6	0.1	0.7
Organics + H_2O^+	1.2	0.1	(0.1)[a]	(2.8)[a]	(1.1)[a]	(4.1)[a]
Total	99.8	99.0	98.8	99.8	98.7	99.2

[a]Excluded from total since the values represent H_2O derived from the chlorite-vermiculte or brucite mineral phases.

Figure 10. Transportation system

and at Villa Florida in southern Paraguay, as well as a reported deposit at Pedro Juan Caballero in northern Paraguay, need more mapping before the total reserves of the country can be estimated. Preliminary examination of a single sample from Pedro Juan Caballero shows it to be a carbonate rock of igneous or metamorphic nature.

Nevertheless, tonnages of limestone already known to exist—as a result of our survey and available reports (9, 22, 31)—are ample for the agricultural and industrial needs of Paraguay for many, many years. Some of the deposits are dolomitic (Vallemi and Villa Florida), some are phosphatic (lower stratum at Coronel Oviedo-Caaguazu), and the remainder are calcitic. Development of the deposits for agricultural use only now is under consideration. Only at Vallemi is there equipment that could be used to crush the rock to the fineness needed for agriculture.

TRANSPORTATION SYSTEM

The transportation system of Paraguay is made up of the three principal modes--rail, river, and road (figure 10). Rail transportation contributes very little to the movement of goods. Each system, however, has certain inherent disadvantages and export-import goods generally move via a combination of two or more systems. At present, the key to transportation for Paraguay is the port at Buenos Aires, Argentina, and the Parana River. Other routes may soon become more useful, such as the ocean port at Paranagua, Brazil, in combination with trucks to Paraguay.

Highways

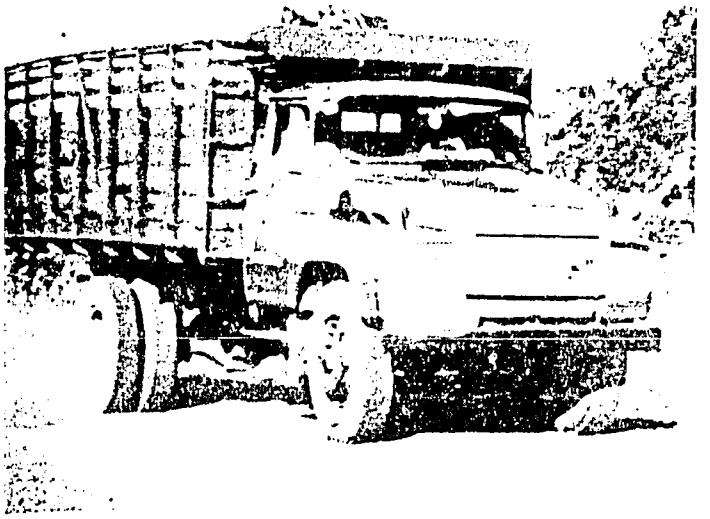
Two main highways (asphalt) presently serve a large proportion of the people in Paraguay. However, these highways represent only about 11% of the total road system. The remaining roads have a crushed-stone base (all-weather) or they are dirt roads which are closed during inclement weather.

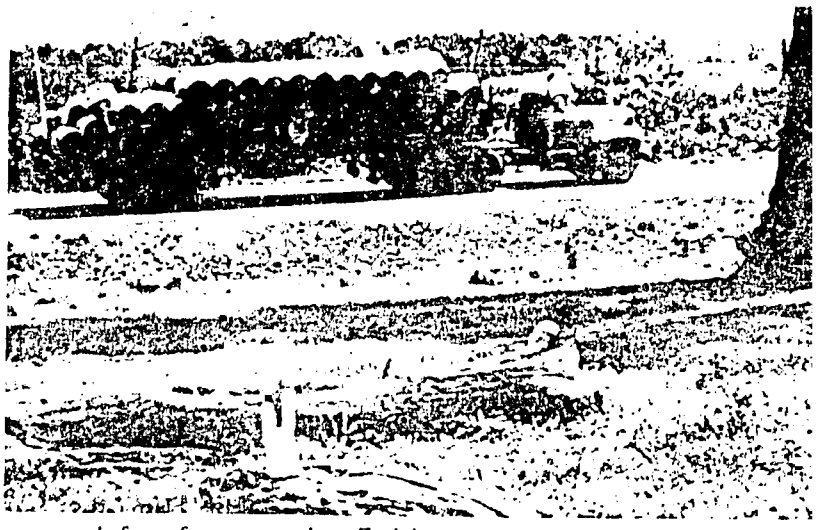
Route 1 (asphalt, 370 km) from Asuncion to Encarnacion connects the country's two largest cities. Much of the farmland and cattle-raising area in the southern part of the country is serviced by this road. At Encarnacion, Highway 1 crosses the Parana River by ferry to connect

Table 23. Typical Truck Freight Rates (12, 13, 53)

From	To	Distance km	Type highway[a]	Rate G/mt/km	Rate $/mt/km	Total cost G/mt	Total cost $/mt
Asuncion	Encarnacion	370	Asphalt	3.25	.0258	1,202	9.55
Asuncion	Puerto Presidente Stroessner	327	Asphalt	3.25	.0258	1,062	8.44
Asuncion	Filadelfia	458	Dirt	3.30	.0262	1,511	12.00
Asuncion	Caaguazu	173	Asphalt	3.10	.0246	536	4.26
Asuncion	Coronel Oviedo	132	Asphalt	3.00	.0238	396	3.14
Asuncion	Pilar	356	Dirt & asphalt	5.00	.0397	1,780	14.15
Asuncion	Pedro Juan Caballero	545	Dirt & asphalt	5.00	.0397	2,720	21.60
Asuncion	Villa Florida	161	Asphalt	3.25	.0258	524	4.15
Asuncion	Santa Rosa	348	Asphalt	3.25	.0258	1,131	8.99
Paranagua[b]	Asuncion	1,100	Asphalt	1.82	.0145	2,003	15.90
Paranagua	Pedro Juan Caballero	1,400	Asphalt & dirt	2.54	.0202	3,560	28.20
Buenos Aires	Asuncion	1,370	Asphalt	2.88	.0229	3,969	31.50
Sao Paulo	Asuncion	1,442	Asphalt	2.57	.0204	3,710	29.40

[a]Only about 11% of the road surfaces in Paraguay are asphalt.
[b]Paraguayan tax of NCr240/truck equivalent to $5.09/mt (10-mt truck) previously charged to Brazilian trucks no longer included.





Trucks such as the one on the left move goods from farm to market. Freight rates are reduced by hauling larger tonnages and by development of backhauls.

with the Posadas-Buenos Aires highway. Another asphalt road (Highway 2 and 7) connects Asuncion to Puerto Presidente Stroessner, a distance of 327 km. This road continues on to the port at Paranagua, Brazil, and provides an alternate route to an ocean port. Farms along this road tend to be small. Other areas of the country are served by roads subject to weather conditions. Filadelfia in the Chaco and Pedro Juan Caballero in the northeast are served by dirt roads which are closed during heavy rainfall. Other cities can be reached in the major population areas by a combination of dirt and asphalt roads. The highway facilitates the transport of goods in the area triangalized by Asuncion, Encarnacion, and Puerto Presidente Stroessner. Most farmers take their goods to some central point in the colonies where they may be collected by trucks. Ultimately, these goods move to markets or warehouses in the larger cities.

Most truck operators bargain for transportation services and rates vary considerably. Also, truck companies will negotiate up to a 25% discount, depending on volume. Table 23 shows typical freight charges, although individual operators may accept lower fees (12, 13, 53). A single-axle truck in Paraguay has a capacity of 10 mt, while an additional 10 mt may be hauled with a dual axle. Some tractor-trailers are now being used with a 30-mt capacity. Numerous pickup trucks are available, especially in the area of Asuncion. The average freight rate for the most significant routes for freight is 3.25 ₲/mt/km (asphalt road). These rates are based primarily on a 10-mt truck with full loads. As indicated previously, rates may be reduced by increases in tonnage and backhauls. As in other Latin American countries, several one-way tolls averaging about 50₲ are encountered. Load limits are not posted but weigh scales limit the load on asphalt to 35 mt. On unpaved surfaces bridges of unknown capacity are the limiting factor.

Rivers and Ports

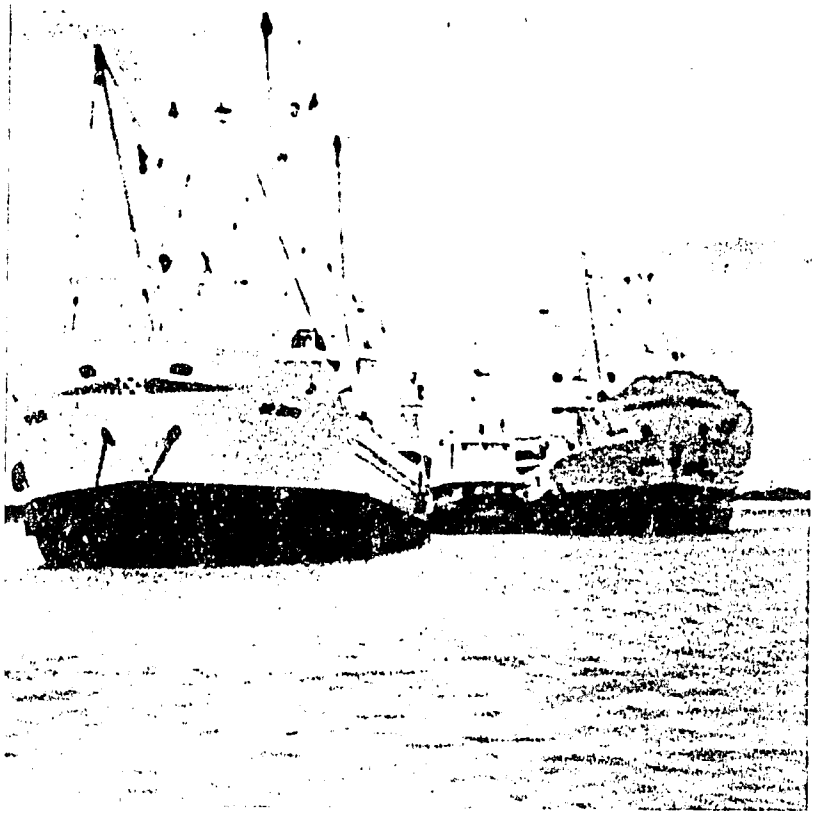
The Parana River is a major route from the ocean port at Buenos Aires, Argentina, to the river port of Asuncion. Ships of about 1,000-mt capacity and belonging to the GOP's FME handle most of the freight for Paraguay. The distance from Asuncion to Buenos Aires via river is 1,136 km. Very few ports and roads exist along the Paraguay River south of Asuncion; thus a large proportion of import and export materials must move through Asuncion. Low water passes and fluctuating river levels create navigation problems and limit the size of ships to about a 1,000-mt maximum. During low water on the Paraguay River, which occurs for 3-5 months of the year, ships are severely limited in the quantity they can haul and freight rates are increased accordingly. Despite the handicaps of the river, a large percentage of import and export goods is moved via the Paraguay and Parana Rivers.

The Parana River also forms the southern and eastern boundary of Paraguay and contributes to the economy of the country. This river suffers from problems similar to those of the Paraguay River. Boats of up to 500-mt capacity only can travel the Parana; just below Encarnacion

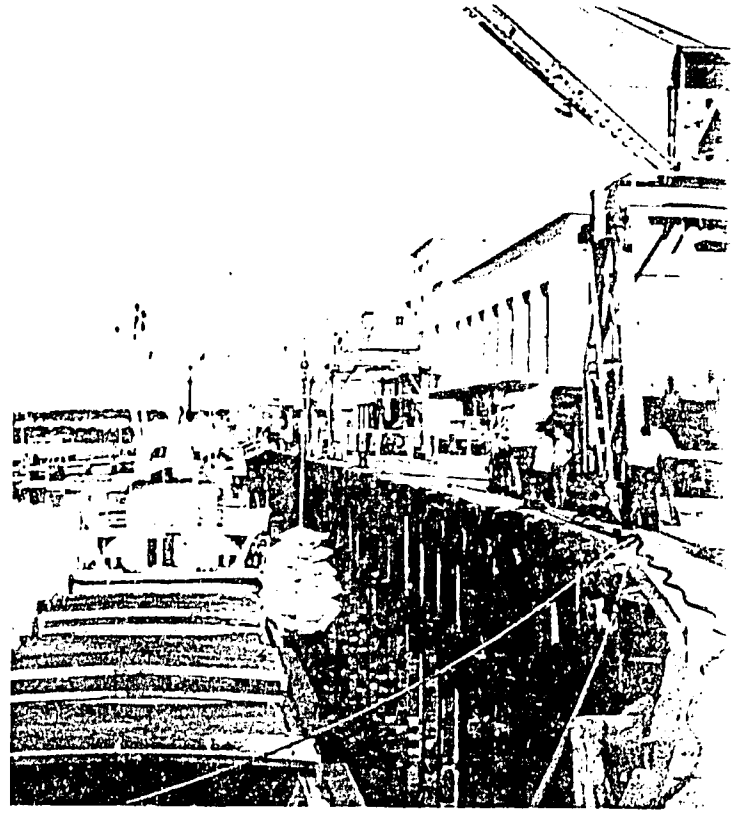
Table 24. Typical Freight Rates Via Water (16, 27)

From	To	Via river	Distance km	Capacity mt	Rate ₲/mt/km	Rate S/mt/km	Total cost ₲/mt	Total cost S/mt
Buenos Aires	Asuncion	Paraguay-Parana	1,136	1,000	1.90	0.015	2,144	17.02
Buenos Aires	Encarnacion	Parana	796	1,000->500[a]	2.28	0.018	1,806	14.33
Encarnacion	Puerto Presidente Stroessner	Parana	340	500	2.28	0.018	771	6.12

[a]Only boats with about 500-mt capacity can travel the Parana River above Confluencia.



Flota Mercante del Estado's ships are small but modern.



Fertilizer moves in bags by boat —or in shallow-draft barge.

the river widens and flows over relatively shallow rapids. Boats can, however, travel the distance (350 km) from the intersecting point of the Paraguay and Parana Rivers eastward to Encarnacion. The most favorable time for passage is the nine months from October through June—high water time. Boats can also travel past Encarnacion to Puerto Presidente Stroessner (350 km). Currently, most cargo on the Parana River is in one direction only: agricultural and lumber products bound downstream for the Buenos Aires port. A proposed dam below Encarnacion would relieve many of the navigation problems of the Parana. Improved river navigation on the Parana could bolster the agricultural economy in southern Paraguay. Better ports and access roads along the Parana probably could be developed and justified if more dependable water transportation and larger boats could be used.

Information gathered about shipping rates on the Paraguay and Parana Rivers is given in table 24. At present, all fertilizer comes to Asuncion in bags. No facilities are available aboard ship or at the port of Asuncion to handle bulk fertilizer. Overhead cranes are available at the port for unloading such items as lumber, sheet steel, and containerized freight. Items are unloaded by means of hooks or clamps. Material can be loaded onto trucks or railroad cars. FME cargo ships have two holds which are covered with tarpaulin during transit. This seal does not prevent the passage of moist air, so that a fertilizer in bulk could absorb water vapor from the air during shipment although protection from rain or spray would be provided. Recently some fertilizer (bagged) has been received by barge. The shallower draft of a barge should permit greater tonnages per load and fewer difficulties with low water. Only a few barges are used at the present time. These barges are no better equipped to handle bulk fertilizers than the FME ships. A fertilizer such as bulk urea would require a moisture-proof hatch to minimize moisture absorption. No facilities are available at the port for handling bulk fertilizer, and no bulk storage is provided. However, the addition of a clam-shell type bucket and a hopper for truck loading could be easily provided. A portion of the storage space for bagged material could be converted to bulk storage easily. The port at Encarnacion has poor access roads and is equipped to handle mainly agricultural products such as yerba mate, tung oil, and lumber products. Much of the river traffic around Encarnacion consists of passenger vessels rather than vessels equipped for freight.

The activities of the Asuncion port are closely tied with the international port at Buenos Aires, Argentina. Buenos Aires port has all the facilities necessary for handling bagged and bulk fertilizers. Unfortunately, Asuncion port at this time cannot take advantage of economies associated with transport of large tonnages and rapid-handling systems. Improvements can be made in the future which will partially offset the disadvantage of smaller-tonnage ships.

Other ports which can handle goods for Paraguay are the ocean ports at Paranagua and Santos, Brazil. Bulk fertilizer can be unloaded at Santos with port facilities but ship's gear must be used at Paranagua. Material must be trucked

to Paraguay through Brazil. Both ports provide a method for getting bulk fertilizer into Paraguay. Roads serving Paraguay through Brazil are improving and if larger trucks can be used in the future (greater than 10-mt capacity) with backhauling, these ports can be expected to play an even greater role in the development of Paraguay.

Railroad

A railroad in Paraguay operates between Asuncion and Encarnacion (370 km) and from San Salvador to General Higinio Marinigo (63 km). At Encarnacion the railroad connects by car ferry across the Parana River with a railroad in Argentina at Posadas. Therefore, a route by rail exists from Asuncion to Buenos Aires, Argentina, but it is severely hampered by the river crossing. This provides an international route through Buenos Aires but several factors contribute to the difficulty of efficient operation of the railroad. Much of the rolling stock is obsolete and the track is in poor condition. No bottom-dumping cars are available to facilitate rapid-handling techniques. A large capital investment would be required to renovate the rail system. Improvements in the highway system have taken freight and passenger traffic which might otherwise move by rail. Sufficient freight tonnage and passengers probably cannot be generated in Paraguay to support a modern rail system. Essentially no raw materials are moved in sufficient quantities in Paraguay to justify a large capital expenditure to improve the rail system.

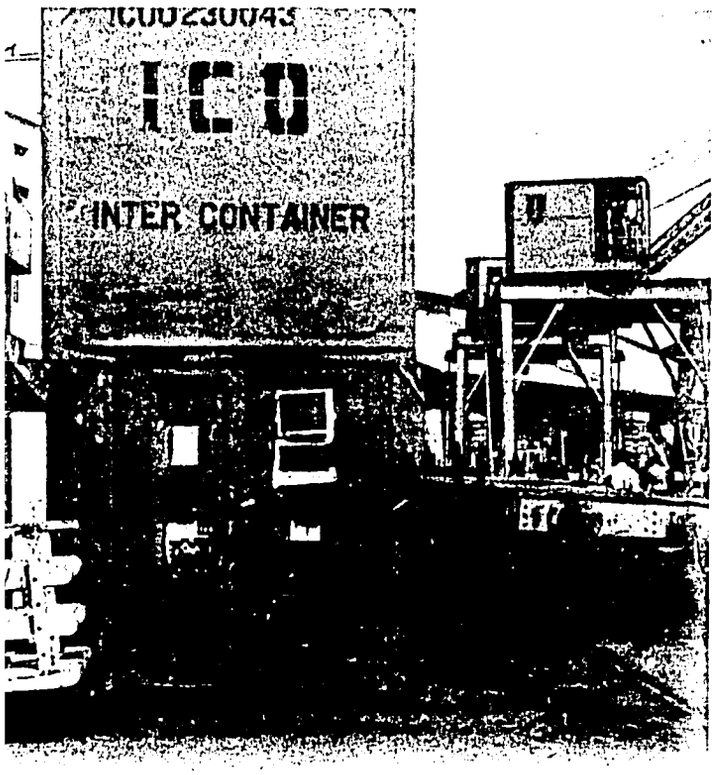
The typical freight rate from Buenos Aires, Argentina, to Asuncion (1,554 km) is $10.64/mt or 1,341 ₲/mt. This is equivalent to $0.0069/mt/km or 0.87 ₲/mt/km. From Pacu-cua (ferry point near Encarnacion) to Asuncion (370 km), the rate is $2.99/mt (377 ₲/mt) or $0.0081/mt/km (1.02 ₲/mt/km). Normally, the one-way time between Asuncion and Encarnacion is two days and six days between Asuncion and Buenos Aires. Each car can carry 30 mt with a capacity per train of 10 cars. Materials moved by train consist mainly of corn and soybeans. Low freight rates for the rail system indicate that the operation probably is not self-supporting. The chances are great that the situation will worsen in the future. Therefore, the use of the rail system for the movement of fertilizer in Paraguay probably will not become significant. If the freight rates could be used with dependable transportation, the railroad would be an attractive mode of transportation. However, if capital expenditures were made to improve the system, rates would undoubtedly increase.

TAXES AND DUTIES

Paraguay

Taxes and duties on imported fertilizers contribute measurably to their total cost. Three types of calculations are needed in determining the total customs charges. These are: (1) variable charges expressed as a percentage of the CIF value, (2) fixed charges per mt, and (3) fixed charges per shipment. CIF values are inflated 20% before customs are calculated. Several charges applicable to agricultural imports, which amounted to about 77% of the CIF value,

Containerized shipment may be the answer to shipping bulk urea to tropical countries.



Rolling stock is obsolete, but modernization of the rail system may not be economically feasible.

are no longer required for fertilizer, insecticides, and farm equipment. These liberated items are shown in table 25 along with charges that are still applicable.

A close approximation for customs charges on imported fertilizer is:

$$\text{Total customs per mt} = \text{CIF value} + 10\% \text{ CIF value} + \$8.13 + \frac{\$5.00}{\text{total tons}}$$

Brazil

Fertilizers for Paraguay can move by ocean shipment through two ports in Brazil—Santos and Paranagua. Charges through these ports are given in table 26 for bagged and bulk fertilizer. Bulk fertilizer can be moved through the port of Paranagua only if the vessel is equipped for bulk unloading; no facilities for bulk unloading are available at the port site. Costs at the port of Paranagua are higher than those at Santos probably because of a lower tonnage throughput. The charge at Santos was $5.42/mt and at Paranagua the charge was $12.98/mt for bagged fertilizer. Bulk handling reduced the cost per ton.

Argentina

The port at Buenos Aires is now the most important port for handling Paraguayan goods. Costs per ton ($5.85) were close to that for Santos. Buenos Aires is equipped to handle bulk shipments.

Table 25. Paraguayan Taxes and Duties on Fertilizer

Type of charge	Cost and basis for cost
Variable charges	% of CIF values[a]
1. Decree No. 18784, dated 1966	1.00
2. Law No. 862	0.50
3. Customs & fiscal inspection	0.51
4. Ministry of Agriculture inspector's per diem	0.17
5. Photostatic copies of consular invoices, etc.	0.28
6. Custom broker's fee + paperwork	2.00
7. Law No. 1003, dated 1964, 5% of amount liberated	3.87
Total	8.33
Fixed charges	$/mt
1. Stamps & fees, Ministry of Finance	4.00
2. Unloading	1.19
3. Delivery to storage	2.94
Total	8.13
Other charges	$/shipment
1. Stamps, etc.	5.00
Liberated charges	% of CIF values[a]
1. Exchange charge (bank expense)	32.0
2. Other (additional)	15.0
3. Complimentary taxes	24.0
4. Consular taxes	5.4
5. Commercial reposition	1.0
Total	77.4

[a]CIF value for tax purposed (Decree No. 292) = (FOB price + insurance + freight) x 1.2.

Table 26. Handling Charges for Fertilizers, Atlantic Coast Ports, 1970 (50)

	Santos, Brazil		Buenos Aires, Argentina		Paranagua, Brazil	
	Bagged	Bulk	Bagged	Bulk	Bagged	Bulk
	NCr/mt		mSn/mt		NCr/mt	
Unloading vessel	–	–	1,050	462	28.00[a]	14.10
Port charges	16.00	7.52	–	–	8.80	8.80
Direct rail loading	–	–	–	455	–	–
Transportation	2.54	2.54	112	112	8.00	8.00
Warehouse—15 days	3.32	–	840	–	2.00	2.00
Other expenses	.19	.18	45	45	.25	.24
Paperwork	.08	.08	–	–	–	–
Other services	.19	.18	–	–	.04	.03
CDA	.89	.89	–	–	–	–
Document copies	.03	.03	–	–	–	–
Agent commission	2.34	2.34	–	–	14.19	14.19
Total port expenses	25.58	13.76	2,047	1,074	61.28	47.36
Total port expenses $[b]	5.42	2.91	5.85	3.07	12.98	10.03

[a]Estimated
[b]Exchange rate: NCr 4.72 = $1.00; mSn 350 = $1.00

The Banco Nacional de Fomento provides credit in the agricultural field.

DISTRIBUTION AND MARKETING SYSTEMS

The use of agricultural lime has just approached the innovator stage; a few farmers are trying it. A few quarry owners, presently calcining the rock for use in the construction industry, are considering production of crushed rock for agricultural use. One company has acquired a tractor-trailer of 40-mt capacity to haul agricultural lime in bulk but does not yet have a crusher installed. The company has started to develop a distribution plan but has not yet developed any marketing plans or organization.

Fertilizer use, while infinitesimal by many standards, is much more advanced than lime use. The distribution system is not complicated. All fertilizer is imported in 50-kg jute bags with polyethylene liners. These are transshipped from ocean freighters in the harbor at Buenos Aires to FME ships or to a barge. At Asuncion the fertilizer is loaded onto trucks for transfer to a warehouse. Most of the fertilizer is stored in Asuncion; in only a few instances is it trucked directly to a warehouse in some other city. Purchasers are expected to come to Asuncion for their fertilizer. Farmers who fertilize a large hectarage purchase fertilizer by the truckload. Small farmers sometimes unite to purchase their fertilizer at the same time. More frequently, each farmer buys a bag or two of fertilizer in Asuncion and then locates a trucker who will haul the fertilizer to the purchaser's village or home for a negotiated fee. Occasionally, the local farmer representing the fertilizer company will purchase several bags of fertilizer and store them in his home for resale to his neighbors.

From a marketing viewpoint, two of the local companies currently active in selling fertilizer represent German interests and the third makes its purchases from the world market. CIF value for fertilizers at the port in Asuncion are high because of the port's inland location. Freight charges from Buenos Aires normally are $17.00/mt but can be higher when the river flow is low. To the CIF value must be added customs and other port charges. The importer's markup varies from 20% to 40% and the salesman's commission is an additional 5%-15% (23). Transportation charges from the warehouse in Asuncion usually are borne by the purchaser. Each of the companies selling fertilizers in Paraguay has local representatives (farmers) in its main sales areas.

AGRICULTURAL CREDIT

Agricultural credit in Paraguay has suffered many severe setbacks in the past 25 years. The first formalized credit for agriculture was offered by the Banco Agricola del Paraguay in 1943; by 1945 the bank had failed. Its successor, the Banco del Paraguay, failed in 1961. Presently, the BNF provides credit in the agricultural field. Like its predecessors, it has difficulty in collecting on its loans but it has managed to survive for nine years. BNF credit is available only to farmers who own their land. Loans larger than ₲50,000 must be approved by a loan committee in Asuncion. Small loans can be approved by the manager of a branch bank providing the field loan officer has submitted a favorable report on the prospective borrower. Recently the bulk of the available credit has gone for the promotion of a single crop and creditors have been a few relatively large commercial farmers.

The small farmer and the farmer without a land title still do not have access to formalized credit except for the National Wheat Program. They must rely on the local dealer or supplier for agricultural input items as well as tools, clothing, food, and even spending money. The crop is pledged for repayment of the "loan." Interest on these loans is approximately 5%/month, compared to the 10% annually charged by BNF. This system perpetuates subsistence agriculture (12, 18, 23, 48).

LIME AND FERTILIZER COMPANIES

Lime Companies

Presently, there is no production of agricultural limestone on an organized basis. Limestone is calcined for use as mortar in the construction industry. A few tons seem to have been used by enterprising farmers because soil test reports showed the soil to be acid. There are plans to produce agricultural limestone.

Fertilizer Companies

BNF is the largest fertilizer importer in Paraguay. Three private companies also import fertilizers. They are Cofarma S.A., Hoechst del Paraguay S.A., and Shell Paraguay, Ltd. Esso has ceased to handle fertilizers but two new companies have been formed to handle them. The new companies are Industria Quimica Paraguaya S.A. (Inquipa) and Nitroquimica Paraguaya. All companies are headquartered in Asuncion.

Cofarma has been importing fertilizers for over a decade and now has an annual volume of 2,000-5,000 mt. All fertilizer is obtained in Germany from companies such as Ruhrstickstoff and Kali Chemische. Principal imports (all bagged in jute with polyethylene liners) are urea, calcium ammonium nitrate, ammonium sulfate, thenia phosphate, muriate and sulfate of potash, 12-12-17-2Mg, and 15-15-15. Cofarma represents Olin when bidding to supply fertilizer under AID loans. The company warehouses most of its fertilizers at Asuncion and has additional storage at Encarnacion. Local distributors occasionally store small amounts of fertilizer at Coronel Oviedo and Puerto Presidente Stroessner. Most of Cofarma's sales are for horticultural and vegetable crops, rice, coffee, and sugarcane. Two agronomists provide technical information and put out fertilizer demonstrations. Credit is provided upon the recommendation of the extension agent (36).

Hoechst began importing fertilizers into Paraguay in 1958. Annual volume now is 1,200-1,400 mt, all bagged and from Germany. Principal imports are 12-12-17-2Mg, 15-15-15, 13-13-20, and urea. Grace fertilizers are handled on AID bids. All fertilizer is warehoused in Asuncion but the company has many farmer agents who resell to smaller farmers. These agents receive a commission of 10%-12% on their sales. Fertilizer sales mostly are for tomatoes, peppers, and some citrus. Rates of application are based on FAV soil test recommendation and farmers follow these fairly well. Almost all farmers buy fertilizer on company credit; no interest is charged for the first six months. Fertilizer demonstrations are used by the company agronomist to promote increased use (56).

Shell has been active in the fertilizer business in Paraguay for about four years only. Volume has been increasing about 100 mt annually. Mixed fertilizers (15-15-15, 12-12-17-2Mg, and 14-14-14) are the leading materials, followed by muriate of potash, diammonium phosphate, and ammonium sulfate. Fertilizer is imported from wherever it can be purchased most economically, such as Holland, the United States, and other countries. For AID tenders, Shell represents International Ore and Fertilizers Corporation. Most sales are for sugarcane and some fertilizer is warehoused in the sugarcane areas. In many cases, the sugar millers provide the credit for fertilizer purchases but Shell provides credit when necessary. Other sales are for potatoes, tomatoes, wheat, soybeans, vegetables, coffee, and rice. Demonstrations are used to promote use on new crops and increased use. Shell also pays for soil tests made by FAV (46).

Inquipa was organized to produce industrial chemicals such as chlorine and caustic soda. The company is considering production of normal superphosphate. Sulfuric acid would be obtained in Buenos Aires and shipped by rail to Asuncion. Phosphate rock would be purchased in the United States. Manufacturing facilities have not been constructed and a marketing organization has not been developed (6).

Nitroquimica is planning a bulk-blending facility in Asuncion on a 50-50 basis with Adela Investment Company S.A. The facility would be similar to those operated by Nitroquimica in Chile, Brazil, and other Latin American countries. Raw materials will be purchased in the United States and trucked to Asuncion from the port at Paranagua, Brazil. Lumber and agricultural products would make up backhaul. Plans are to bag all product during the first year and sell through BNF, thus avoiding credit problems. The plant is expected to be on-stream by December 1970 (44, 52).

Since 1968 BNF has been the most important importer of fertilizer. Starting in a modest way in 1964, the bank has consistently increased its volume of imports to the point that 90% of the fertilizer now passes through its warehouses in Asuncion. Ostensibly, BNF purchases its fertilizer from local private enterprise on a low-bid basis. In actuality these local businesses, except for the companies listed above, are brokers who import fertilizers only when awarded a bid. In rare instances a fertilizer company can consolidate its purchases with those made for BNF and gain some benefit in purchase price for the larger order. BNF, because it is a governmental organization, helps plan agricultural development programs. It also provides the credit needed for many of these programs. Consequently, most commercial farmers make most of their purchases from the bank. Markup for fertilizer, to cover costs of storage and administration, is about 15% (23).

Section V

POTENTIAL USE FOR LIME AND FERTILIZER

BASIS FOR FERTILIZER PROJECTIONS

Projection of fertilizer use in a rapidly changing agrarian society is subject to a wide variety of inherent errors. At the outset, the area under cultivation of cash crops may change considerably in a relatively short time if marketing characteristics change. Long-range predictions are affected by external as well as internal demands, changes in government policy, and changes in benefit/cost ratios involved in the production. The economic advantages of producing one crop over another change at the country level as well as the farmer level in response to supply and demand. Predictions are more difficult if the alternatives available for exploitation are of a broad-range nature. On the other hand, as the alternative use of land and crops becomes more limited, the prediction possibilities improve.

A fairly simple set of guidelines has been employed in projecting fertilizer needs for Paraguay. These are outlined briefly below.

CROP PRIORITIES AND POTENTIALS

Crops that have been selected by the GOP for emphasis in either import substitutions or export expansion are calculated at a net growth expansion in hectarage as well as yields per hectare. Projected area (hectare) growth is based on the kind of farming (mechanized or not), the availability of soils for the kind of exploitation considered, and the kinds of incentive policy offered to the farmer to acquire and manage additional lands. Increase in the area of fertilized land is expected to be rapid among the more progressive growers but the decrease in nonfertilized land is assumed to be slow because the introduction of new technology (fertilizer) to the small, subsistence, traditional landholders will be difficult.

Crops in which the country is already self-sufficient and in which little potential is foreseen for export expansion are projected on a growth rate similar to population growth. Total area under production of these crops is held constant and the required slow growth is achieved by gradually increasing fertilized area and decreasing the nonfertilized area. Historically, there are usually enough "innovator" farmers who, given a good benefit/cost ratio, will try new technology. Once these farmers begin employing new technology their costs of inputs increase. Use of fertilizer and lime is very important in these cases because yield increases are closely related to these inputs and unit costs cannot be minimized unless production is improved.

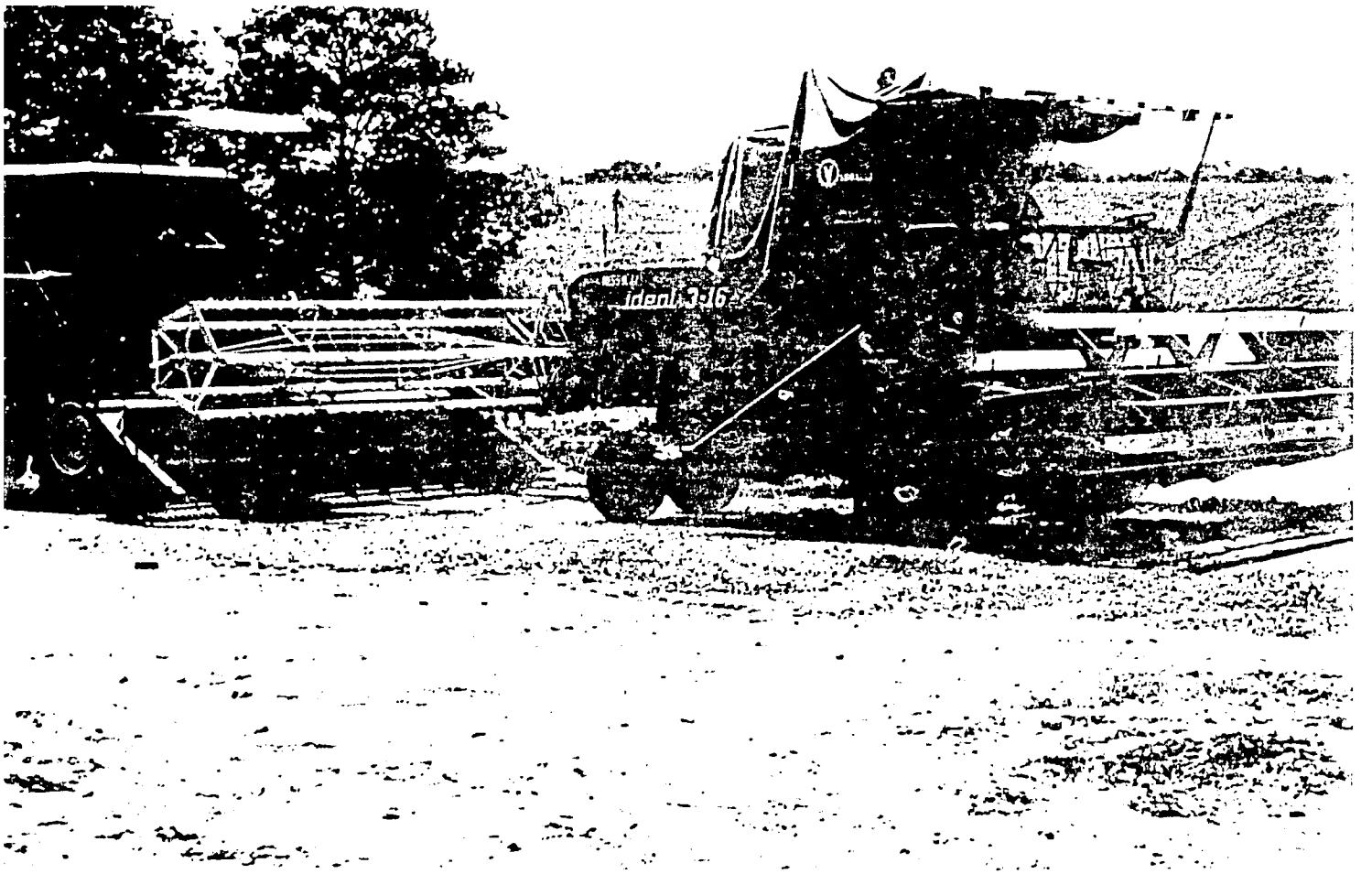
SOIL FERTILITY PATTERNS

Long-term projections are based on general fertilizer recommendations for various crops. General recommendations consider soil fertility patterns (as illustrated in table 2), physical and other characteristics of soils (figure 4), and information about the response of various crops to fertilizers. Paraguay has developed general fertilizer recommendations for some crops but the rates are rather low due to the high cost of fertilizer (26). The TVA team revised most of the rates upward in anticipation of lower prices for fertilizer.

Two types of recommendations were made: corrective and annual. Corrective recommendations are those considered necessary to ready a soil for crop production. Many soils, as shown in tables 2 and 3, are so low in available phosphorus and potassium and so high in acidity or soluble aluminum that little or no response can be obtained from fertilizers at the usual rates of application. Corrective treatments of lime and fertilizer are required to make these soils productive. When viewed in this context, corrective treatments are just as essential as clearing an area of trees or breaking a sod for future cultivation. After the fertility is built up beyond a certain level, called the critical level, relatively low rates of fertilizer can be used to obtain satisfactory crop yields and to maintain fertility above the critical level. Corrective treatments require unusual amounts of lime and fertilizer.

Corrective treatments are considered as a one-time treatment in this report. Phosphorus does not leach or even move readily in the soil. A corrective treatment, then, is a permanent correction provided subsequent treatments at least replenish the amounts lost through crop removal. As shown in table 2, about 90% of the soil samples analyzed were deficient in available phosphorus. Dividing the country into three zones does not stratify phosphorus-deficient soils. Consequently, in the fertilizer projections that follow, phosphorus requirements do not change with zone.

Potassium also can be built up in the soil but not to as



New technology is expensive unless it decreases the cost of production.

high a level as phosphorus. Leaching occurs on the coarser-textured soils and soil acidity also enhances potassium losses. Thus, a medium level of available potassium is the goal desired from corrective fertilization. Table 2 shows that there is a difference in potassium fertility with agricultural zone. In the northern zone 66% of the samples were deficient in potassium but in the central and southern zones the percentage drops to 43%–44%. This difference is reflected in projections by the higher rate of potassium application used for crops in the northern zone. Potassium rates for southern soils are less than for central-zone soils because soil textures are finer in the south. (Southern soils are hydromorphic or developed from basalt as compared to development from sandstone in the central area.)

Nitrogen cannot be stored in the soil except in organic form and this nutrient is not included in any corrective treatments.

Annual treatments are those applied independently of a corrective treatment. These applications vary with the kinds of crops grown, yield goals, moisture regime, and the many other factors that affect fertilizer rates. Nitrogen is a very prominent component of an annual application except for leguminous and sugar crops. Nitrogen frequently is applied more than once during a crop season but this distinction is not essential for fertilizer projections.

PROJECTED FERTILIZER NEEDS BY CROP

Wheat and Soybeans

Wheat and soybeans frequently follow each other in the field. They are considered as a double-crop system of farming rather than as a rotation because both crops are produced in the same year. They are considered together in the fertilizer projections with all the fertilizer for both crops being applied prior to wheat planting. Not more than half the fertilized wheat area should be double-cropped with soybeans to aid in establishing a long-range soil conservation program. The anticipated increase in area, yields, and total wheat production is given in table 27. The increase in fertilized area for the next 5 years will be at a slower rate than the big increases made between 1969 and 1970. This will permit more control of the program and an improvement in management of all parts of the technology package which is so critical in the wheat program.

The yield levels projected for fertilized wheat begin at 1,400 kg/ha in 1971 and increase to 1,600 kg/ha in 1976. Higher yields can be obtained with the new dwarf varieties but average yields are not likely to exceed this level due to inherent losses in harvesting caused by the spring rains. Average yields of nonfertilized wheat will decline on soils

subjected to continuous cropping in the absence of fertilizer although new fields will have a higher potential for the first few years. The projected hectarage of nonfertilized wheat will decline very slowly as these represent traditional growers on small properties, most of whom probably will have some difficulty in getting fertilizer credit.

As those presently associated with the wheat program can confirm, a number of technological problems exist that will make the proposed rate of growth a real challenge and will make self-sufficiency very difficult before 1978 and perhaps not then. At the yield level indicated, benefit/cost ratio in wheat (soybeans) is among the lowest of the crops to be fertilized. Nevertheless, the ratio is high enough for a sound economic program both for the farmer and the country. From the farmer's point of view, land used for wheat production has essentially no alternate use during the winter period and the same mechanized equipment can be used for both wheat and soybeans. The technique of fertilizer application by bulk spreading in advance of wheat planting could improve the overall efficiency of getting both crops in faster and with less difficulty (see section VI for further discussion of fertilizer use technology in wheat). Finally, double-cropping itself is an advantage in cases where fairly high levels of capital are involved in corrective applications of lime and phosphate. This correction increases the cost (and value) of the land but, since it is a fixed cost, it is profitable to spread it out over as many crops in as short a time as possible.

If the GOP policy on wheat production continues to provide the incentives which permit expansion, the increase in wheat-soybean area should be attainable. Problems of rust and wheat disease must be brought under better control, of course, through a continuing program of varietal testing. If variety improvement and multiplication encounter difficulty, the goals in area will have to be held back accordingly.

Since the fertilizer projections for wheat include soybean fertilization, a separate table for soybean hectarage and yields was not developed. No fertilizer projections were made for sorghum, another crop which may alternate with soybeans as the summer crop in some cases. Farmers report a problem with volunteer growth of sorghum in the next wheat crop, however, so that this combination may not become very popular.

The projected needs for wheat and soybeans are indicated in table 28. Since double-cropping is projected for alternate years, the fertilizer formula is set high enough to meet the needs of both crops, as well as to correct or maintain soil fertility, in accordance with the needs of the soil.

Tobacco

The expansion of tobacco production should include quality improvement as well as increases in both area and yield (table 29). An increase in value of tobacco depends on improved quality more than on higher yields. Present yields are reasonably good because a considerable portion of the tobacco is planted on newly cleared forest soils. Quality is poor under these conditions because the level of nitrogen in these soils is too high. The National Tobacco Program plans to correct this problem by gradually shifting production to soils that have been cultivated for longer periods. However, the tobacco grown on soils of low nitrogen content will produce better quality only if fertilized with relatively high amounts of phosphorus and potassium. Projections for fertilizer needs in tobacco are given in table 30.

Cotton

The expansion of cotton production will be gradual because it has restricted export possibilities. The total area

Table 27. Projected Area, Yield, and Production of Wheat, 1971-1980

Year	Area			Yield		Production		
	Total	Fertilized	Nonfertilized	Fertilized	Nonfertilized	Fertilized	Nonfertilized	Total
		ha		kg/ha		mt		
1971	44,000	25,000	19,000	1,400	700	35,000	13,300	48,300
1972	50,500	32,500	18,000	1,450	700	47,125	12,600	59,725
1973	57,000	40,000	17,000	1,500	700	60,000	11,900	71,900
1974	66,000	50,000	16,000	1,500	700	75,000	11,200	86,200
1975	77,500	62,500	15,000	1,500	600	93,750	9,000	102,750
1976	89,000	75,000	14,000	1,600	600	120,000	8,400	128,400
1977	103,000	90,000	13,000	1,600	600	144,000	7,800	151,800
1978	117,000	105,000	12,000	1,600	600	168,000	7,200	175,200[a]
1979	121,000	110,000	11,000	1,600	600	174,000	6,600	180,600[a]
1980	125,000	115,000	10,000	1,600	500	184,000	5,000	189,000[a]

[a]Indicates self-sufficiency.

Table 28. Projected Corrective and Annual Nutrient Needs for Wheat-Soybean Production, 1971-1980

Year	Type of fertilization[a]	Area to be fertilized	Rate of application (N-P_2O_5-K_2O)	Total nutrients N	P_2O_5	K_2O
		ha	kg/ha		mt	
1971	Corrective	25,000				
	Northern zone	8,400	0-120-80	0	1,008	672
	Central zone	9,300	0-120-60	0	1,116	558
	Southern zone	7,300	0-120-40	0	876	292
	Annual	25,000	60-45-45	1,500	1,125	1,125
	Total			1,500	4,125	2,647
1972	Corrective	7,500				
	Northern zone	2,500	0-120-80	0	300	200
	Central zone	2,800	0-120-60	0	336	168
	Southern zone	2,200	0-120-40	0	264	88
	Annual	32,500	60-45-45	1,950	1,462	1,462
	Total			1,950	2,362	1,918
1973	Corrective	7,500				
	Northern zone	2,500	0-120-80	0	300	200
	Central zone	2,800	0-120-60	0	336	168
	Southern zone	2,200	0-120-40	0	264	88
	Annual	40,000	60-45-45	2,400	1,800	1,800
	Total			2,400	2,700	2,256
1974	Corrective	10,000				
	Northern zone	3,400	0-120-80	0	408	272
	Central zone	3,700	0-120-60	0	444	222
	Southern zone	2,900	0-120-40	0	348	116
	Annual	50,000	60-45-45	3,000	2,250	2,250
	Total			3,000	3,450	2,860
1975	Corrective	12,500				
	Northern zone	4,200	0-120-80	0	504	336
	Central zone	4,600	0-120-60	0	552	276
	Southern zone	3,700	0-120-40	0	444	148
	Annual	62,500	60-45-45	3,750	2,812	2,812
	Total			3,750	4,312	3,572
1976	Corrective	12,500				
	Northern zone	4,200	0-120-80	0	504	336
	Central zone	4,600	0-120-60	0	552	276
	Southern zone	3,700	0-120-40	0	444	148
	Annual	75,000	70-50-50	5,250	3,750	3,750
	Total			5,250	5,250	4,510
1977	Corrective	15,000				
	Northern zone	5,000	0-120-80	0	600	400
	Central zone	5,600	0-120-60	0	672	336
	Southern zone	4,400	0-120-40	0	528	176
	Annual	90,000	70-50-50	6,300	4,500	4,500
	Total			6,300	6,300	5,412
1978	Corrective	15,000				
	Northern zone	5,000	0-120-80	0	600	400
	Central zone	5,600	0-120-60	0	672	336
	Southern zone	4,400	0-120-40	0	528	176
	Annual	105,000	70-50-50	7,350	5,250	5,250
	Total			7,350	7,050	6,160
1979	Corrective	5,000				
	Northern zone	1,700	0-120-80	0	204	136
	Central zone	1,800	0-120-60	0	216	108
	Southern zone	1,500	0-120-40	0	180	60
	Annual	110,000	70-50-50	7,700	5,500	5,500
	Total			7,700	6,100	5,804
1980	Corrective	5,000				
	Northern zone	1,700	0-120-80	0	204	136
	Central zone	1,800	0-120-60	0	216	108
	Southern zone	1,500	0-120-40	0	180	60
	Annual	115,000	70-50-50	8,050	5,750	5,750
	Total			8,050	6,350	6,054

[a]Annual fertilizer is applied each crop year. Wheat and soybeans are double-cropped in alternate years.

Table 29. Projected Area, Yield, and Production of Tobacco, 1971-1980

Year	Area			Yield		Production		
	Total	Fertilized	Nonfertilized	Fertilized	Nonfertilized	Fertilized	Nonfertilized	Total
		ha		mt/ha		mt		
1971	20,000	1,500	18,500	1.4	1.2	2,100	22,200	24,300
1972	20,500	2,000	18,500	1.5	1.2	3,000	22,200	25,200
1973	21,000	2,500	18,500	1.5	1.2	3,750	22,200	25,950
1974	21,500	3,000	18,500	1.6	1.2	4,800	22,200	27,000
1975	22,000	4,000	18,000	1.6	1.2	6,400	21,600	28,000
1976	22,500	5,000	17,500	1.6	1.2	8,000	21,000	29,000
1977	23,000	6,000	17,000	1.6	1.2	9,600	20,400	30,000
1978	23,500	7,500	16,000	1.6	1.2	12,000	19,200	31,200
1979	24,000	9,000	15,000	1.6	1.2	14,400	18,000	32,400
1980	24,500	10,500	14,000	1.6	1.2	16,800	16,800	33,600

Table 30. Projected Nutrient Needs for Tobacco, 1971-1980

Year	Agricultural zone	Area to be fertilized	Rate of application (N-P_2O_5-K_2O)	Total nutrients		
				N	P_2O_5	K_2O
		ha	kg/ha		mt	
1971	Northern	270	50-80-120	14	22	32
	Central	900	50-80-100	45	72	90
	Southern	330	50-80-80	16	26	26
	Total	1,500		75	120	148
1972	Northern	360	50-80-120	18	29	43
	Central	1,200	50-80-100	60	96	120
	Southern	440	50-80-80	22	35	35
	Total	2,000		100	160	198
1973	Northern	450	50-80-120	22	36	54
	Central	1,500	50-80-100	75	120	150
	Southern	550	50-80-80	28	44	44
	Total	2,500		125	200	248
1974	Northern	540	50-80-120	27	43	65
	Central	1,800	50-80-100	90	144	180
	Southern	660	50-80-80	33	53	53
	Total	3,000		150	240	298
1975	Northern	720	50-80-120	36	58	86
	Central	2,400	50-80-100	120	192	240
	Southern	880	50-80-80	44	70	70
	Total	4,000		200	320	396
1976	Northern	900	50-80-120	45	72	108
	Central	3,000	50-80-100	150	240	300
	Southern	1,100	50-80-80	55	88	88
	Total	5,000		250	400	496
1977	Northern	1,080	50-80-120	54	86	130
	Central	3,600	50-80-100	180	288	360
	Southern	1,320	50-80-80	66	106	106
	Total	6,000		300	480	596
1978	Northern	1,350	50-80-120	68	108	162
	Central	4,500	50-80-100	225	360	450
	Southern	1,650	50-80-80	82	132	132
	Total	7,500		375	600	744
1979	Northern	1,620	50-80-120	81	130	194
	Central	5,400	50-80-100	270	432	540
	Southern	1,980	50-80-80	99	158	158
	Total	9,000		450	720	892
1980	Northern	1,800	50-80-120	90	144	216
	Central	6,000	50-80-100	300	480	600
	Southern	2,200	50-80-80	110	176	176
	Total	10,000		500	800	992

Table 31. Projected Area, Yield, and Production of Cotton, 1971-1980

Year	Area			Yield		Production		
	Total	Fertilized	Nonfertilized	Fertilized	Nonfertilized	Fertilized	Nonfertilized	Total
		ha		kg/ha		mt		
1971	60,000	1,000	59,000	2,000	650	2,000	38,350	40,350
1972	60,000	2,000	58,000	2,000	650	4,000	37,700	41,700
1973	60,000	3,000	57,000	2,100	650	6,100	37,050	43,150
1974	60,000	4,000	56,000	2,200	650	8,800	36,400	45,200
1975	60,000	5,000	55,000	2,300	650	11,500	35,750	47,250
1976	60,000	6,000	54,000	2,400	650	14,400	35,100	49,500
1977	60,000	7,000	53,000	2,500	650	17,500	34,450	51,950
1978	60,000	8,000	52,000	2,600	650	20,800	33,800	54,600
1979	60,000	9,000	51,000	2,700	650	24,300	33,150	57,450
1980	60,000	10,000	50,000	2,700	650	27,000	32,500	59,500

is projected to be constant (table 31) and increases in production brought about gradually through a shift to use of fertilizer on the more progressive farms. An improvement in competitive position of the Paraguayan cotton producers can only be obtained by reducing unit costs. Proper use of fertilizer should do this because substantial yield improvement is possible. Fertilizer need projections for cotton will be modest (table 32).

Corn

Corn yields are not very high in Paraguay. Neither is the price. Although yield can be increased by using fertilizer, few of the traditional farmers are expected to do so. The benefit/cost ratio just isn't high enough. Nevertheless, some fertilizer use has been projected, along with an increase in production comparable to the increase in population. There always will be a few innovators who are able to make a profit from fertilizing corn. Some will feed the corn to livestock and others will find some other suitable market. Some wheat farmers probably will plant corn in a few fields prepared for wheat but, for one reason or another, not planted. Rather than to lose production for an entire year, corn can be planted later. Table 33 shows that less than 20% of the total hectarage is projected for fertilization within the next decade. Total fertilizer requirements for corn are not high (table 34).

Rice

Expansion in rice production is projected as a combination of increased hectarage and increased yields (table 35). Some of the additional production will be exported and the remainder will be used domestically by the expanding population. Flooded rice is less responsive to phosphorus fertilization than crops on upland soils. Consequently, table 36 shows a relatively low need for this plant nutrient.

Sugarcane

No change in total area under production is projected for sugarcane (table 37); rather a gradual shift to use of fertilizer will be made in order to improve sugarcane production on soils that are extremely infertile due to many years of continuous cropping. Sugarcane responses to fertilizer should lower unit costs considerably and improve the efficiency of production for the innovator farmers. Only a relatively modest trend is projected for total fertilizer use in sugarcane, however (table 38).

Corn and other crops will justify fertilizer use only if the benefit/cost ratio is sufficiently high.

Table 32. Projected Corrective and Annual Nutrient Needs for Cotton, 1971-1980

Year	Type of fertilization	Area to be fertilized	Rate of application (N-P_2O_5-K_2O)	Total nutrients N	P_2O_5	K_2O
		ha	kg/ha		mt	
1971	Corrective	1,000				
	Northern zone	60	0-120-80	0	7	5
	Central zone	550	0-120-60	0	66	33
	Southern zone	390	0-120-40	0	47	16
	Annual	1,000	80-40-55	80	40	55
	Total			80	160	109
1972	Corrective	1,000				
	Northern zone	60	0-120-80	0	7	5
	Central zone	550	0-120-60	0	66	33
	Southern zone	390	0-120-40	0	47	16
	Annual	2,000	80-40-55	160	80	110
	Total			160	200	164
1973	Corrective	1,000				
	Northern zone	60	0-120-80	0	7	5
	Central zone	550	0-120-60	0	66	33
	Southern zone	390	0-120-40	0	47	16
	Annual	3,000	80-40-55	240	120	165
	Total			240	240	219
1974	Corrective	1,000				
	Northern zone	60	0-120-80	0	7	5
	Central zone	550	0-120-60	0	66	33
	Southern zone	390	0-120-40	0	47	16
	Annual	4,000	80-40-55	320	160	220
	Total			320	280	274
1975	Corrective	1,000				
	Northern zone	60	0-120-80	0	7	5
	Central zone	550	0-120-60	0	66	33
	Southern zone	390	0-120-40	0	47	16
	Annual	5,000	80-40-55	400	200	275
	Total			400	320	329
1976	Corrective	1,000				
	Northern zone	60	0-120-80	0	7	5
	Central zone	550	0-120-60	0	66	33
	Southern zone	390	0-120-40	0	47	16
	Annual	6,000	100-45-65	600	270	390
	Total			600	390	444
1977	Corrective	1,000				
	Northern zone	60	0-120-80	0	7	5
	Central zone	550	0-120-60	0	66	33
	Southern zone	390	0-120-40	0	47	16
	Annual	7,000	100-45-65	700	315	455
	Total			700	435	509
1978	Corrective	1,000				
	Northern zone	60	0-120-80	0	7	5
	Central zone	550	0-120-60	0	66	33
	Southern zone	390	0-120-40	0	47	16
	Annual	8,000	100-45-65	800	360	520
	Total			800	480	574
1979	Corrective	1,000				
	Northern zone	60	0-120-80	0	7	5
	Central zone	550	0-120-60	0	66	33
	Southern zone	390	0-120-40	0	47	16
	Annual	9,000	100-45-65	900	405	585
	Total			900	525	639
1980	Corrective	1,000				
	Northern zone	60	0-120-80	0	7	5
	Central zone	550	0-120-60	0	66	33
	Southern zone	390	0-120-40	0	47	16
	Annual	10,000	100-45-65	1,000	450	650
	Total			1,000	570	704

Table 33. Projected Area, Yield, and Production of Corn, 1971-1980

Year	Area			Yield		Production		
	Total	Fertilized	Nonfertilized	Fertilized	Nonfertilized	Fertilized	Nonfertilized	Total
		ha		mt/ha		mt		
1971	150,000	2,000	148,000	3.5	1.2	7,000	177,600	184,600
1972	150,000	4,000	146,000	3.5	1.2	13,500	175,200	188,700
1973	150,000	6,000	144,000	3.5	1.2	19,500	172,800	192,300
1974	150,000	8,000	142,000	3.6	1.2	28,800	170,400	199,200
1975	150,000	10,000	140,000	3.7	1.2	37,000	168,000	205,000
1976	150,000	13,000	137,000	3.8	1.2	49,400	164,400	214,800
1977	150,000	16,000	134,000	3.9	1.2	62,400	160,800	223,200
1978	150,000	19,000	131,000	4.0	1.2	72,000	157,200	229,200
1979	150,000	23,000	127,000	4.1	1.2	94,300	152,400	246,700
1980	150,000	28,000	122,000	4.2	1.2	117,600	146,400	264,000

Vegetables

Fertilization of vegetables is usually a very profitable practice for growers near good markets. Fertilizer use in onions, potatoes, and tomatoes has accounted for a significant portion of fertilizers sold by fertilizer dealers in Paraguay.

The trend to continue expansion of fertilized area in these crops will continue strong as long as market outlets continue. Onions, previously an imported crop, could have a small export potential. Some export possibilities might be available for tomatoes. Potato production could be improved considerably within the current consumption pattern of Paraguay. The total effect of area expansion and fertilizer needs is difficult to predict but chances are good that vegetable growers will be one of the bigger users of fertilizers in the next decade (table 39).

Tree Crops

Coffee and fruits are very responsive to fertilizer applications. Coffee production could be significantly increased in Paraguay if frost damage can be controlled through overhead irrigation. Total growth in fertilizer use for these kinds of tree crops are projected in table 40. About half of the hectarage of fertilized tree crops will be in the northern zone (coffee) and the remainder divided between the two other zones.

Forages

As the dairy industry develops around the population centers, the need to fertilize rather small areas of land for intensive production of forages will increase. A small amount of fertilizer is projected for this kind of use (table 41). Most of this fertilizer will be used in the central zone.

Summary

A summary of projected fertilizer needs is presented in table 42. Total needs for N, P_2O_5, and K_2O by crop indicate that wheat-soybeans, corn, vegetables, and cotton will be the most important users of fertilizer. Total fertilizer nutrient projections for 1975 are 6,902; 7,286; and 6,577 mt of N, P_2O_5, and K_2O respectively. By 1980 use should increase 232%, 176%, and 203% to 16,040; 12,842; and 13,380 mt of N, P_2O_5, and K_2O, respectively. During the 1970-1975 period, corrective applications of phosphorus result in a need for proportionately more of this nutrient than either nitrogen or potassium. After 1975 fewer soils require corrective phosphorus. Nitrogen and potassium needs then surpass phosphorus because the annual maintenance requirements for these two nutrients are higher.

Fruits such as bananas are very responsive to fertilizer

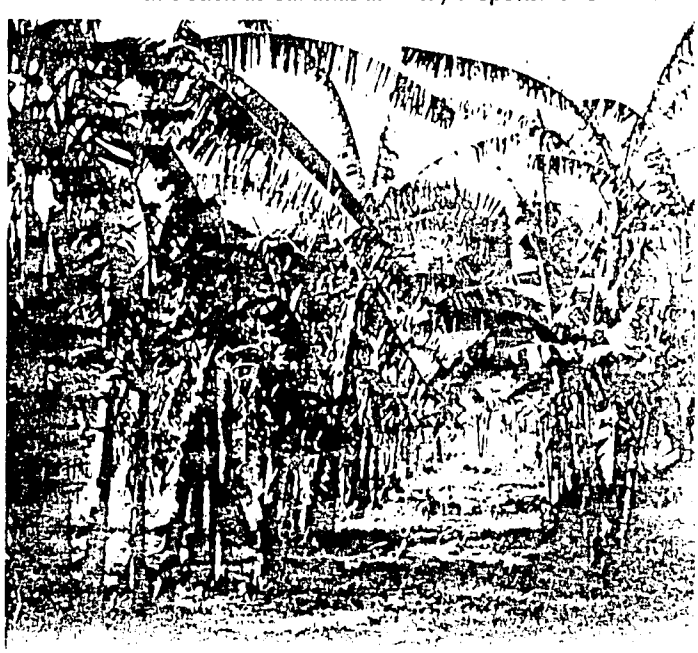


Table 34. Projected Corrective and Annual Nutrient Needs for Corn Production, 1971-1980

Year	Type of fertilization	Area to be fertilized	Rate of application (N-P_2O_5-K_2O)	Total nutrients N	P_2O_5	K_2O
		ha	kg/ha		mt	
1971	Corrective	2,000				
	Northern zone	220	0-120-80	0	26	18
	Central zone	1,100	0-120-60	0	132	66
	Southern zone	680	0-120-40	0	82	27
	Annual	2,000	80-40-55	160	80	110
	Total			160	320	221
1972	Corrective	2,000				
	Northern zone	220	0-120-80	0	26	18
	Central zone	1,100	0-120-60	0	132	66
	Southern zone	680	0-120-40	0	82	27
	Annual	4,000	80-40-55	320	160	220
	Total			320	400	331
1973	Corrective	2,000				
	Northern zone	220	0-120-80	0	26	18
	Central zone	1,100	0-120-60	0	132	66
	Southern zone	680	0-120-40	0	82	27
	Annual	6,000	80-40-55	480	240	330
	Total			480	480	441
1974	Corrective	2,000				
	Northern zone	220	0-120-80	0	26	18
	Central zone	1,100	0-120-60	0	132	66
	Southern zone	680	0-120-40	0	82	27
	Annual	8,000	80-40-55	640	320	440
	Total			640	560	551
1975	Corrective	2,000				
	Northern zone	220	0-120-80	0	26	18
	Central zone	1,100	0-120-60	0	132	66
	Southern zone	680	0-120-40	0	82	27
	Annual	10,000	80-40-55	800	400	550
	Total			800	640	661
1976	Corrective	3,000				
	Northern zone	330	0-120-80	0	40	26
	Central zone	1,650	0-120-60	0	198	99
	Southern zone	1,020	0-120-40	0	122	41
	Annual	13,000	100-45-65	1,300	585	845
	Total			1,300	945	1,011
1977	Corrective	3,000				
	Northern zone	330	0-120-80	0	40	26
	Central zone	1,650	0-120-60	0	198	99
	Southern zone	1,020	0-120-40	0	122	41
	Annual	16,000	100-45-65	1,600	720	1,040
	Total			1,600	1,080	1,206
1978	Corrective	3,000				
	Northern zone	330	0-120-80	0	40	26
	Central zone	1,650	0-120-60	0	198	99
	Southern zone	1,020	0-120-40	0	122	41
	Annual	19,000	100-45-65	1,900	855	1,235
	Total			1,900	1,215	1,401
1979	Corrective	4,000				
	Northern zone	440	0-120-80	0	53	35
	Central zone	2,200	0-120-60	0	264	132
	Southern zone	1,360	0-120-40	0	163	54
	Annual	23,000	100-45-65	2,300	1,035	1,495
	Total			2,300	1,515	1,716
1980	Corrective	5,000				
	Northern zone	550	0-120-80	0	66	44
	Central zone	2,750	0-120-60	0	330	165
	Southern zone	1,700	0-120-40	0	204	68
	Annual	28,000	100-45-65	2,800	1,260	1,820
	Total			2,800	1,860	2,097

Table 35. Projected Area, Yield, and Production of Rice, 1971-1980

Year	Area[a] Total	Area[a] Fertilized	Area[a] Nonfertilized	Yield Fertilized	Yield Nonfertilized	Production Fertilized	Production Nonfertilized	Production Total
	ha			kg/ha		mt		
1971	10,000	1,000	9,000	4,500	2,400	4,500	21,600	26,100
1972	11,000	2,000	9,000	4,500	2,400	9,000	21,600	30,600
1973	12,000	3,000	9,000	4,500	2,400	13,500	21,600	35,100
1974	13,000	4,000	9,000	4,800	2,400	19,200	21,600	40,800
1975	14,000	5,000	9,000	4,800	2,400	24,000	21,600	45,600
1976	15,000	6,000	9,000	5,000	2,400	30,000	21,600	51,600
1977	16,000	7,000	9,000	5,000	2,400	35,000	21,600	56,600
1978	17,000	8,000	9,000	5,000	2,400	35,000	21,600	61,600
1979	18,000	9,000	9,000	5,000	2,400	45,000	21,600	66,600
1980	19,000	10,000	9,000	5,000	2,400	50,000	21,600	71,600

[a]Some fields are double cropped with rice, so actual field area is less than the rice area.

Table 36. Projected Nutrient Needs for Rice, 1971-1980

Year	Agricultural zone	Area to be fertilized	Rate of application (N-P_2O_5-K_2O)	Total nutrients N	Total nutrients P_2O_5	Total nutrients K_2O
		ha	kg/ha		mt	
1971	Northern	50	60-40-60	3	2	3
	Central	320	60-40-40	19	13	13
	Southern	630	60-40-20	38	25	13
	Total	1,000		60	40	29
1972	Northern	100	60-40-60	6	4	6
	Central	640	60-40-60	38	26	26
	Southern	1,260	60-40-20	76	50	25
	Total	2,000		120	80	57
1973	Northern	150	60-40-60	9	6	9
	Central	960	60-40-40	58	38	38
	Southern	1,890	60-40-20	113	76	38
	Total	3,000		180	120	85
1974	Northern	200	60-40-60	12	8	12
	Central	1,280	60-40-40	77	51	51
	Southern	2,520	60-40-20	151	101	50
	Total	4,000		240	160	113
1975	Northern	250	60-40-60	15	10	15
	Central	1,600	60-40-40	96	64	64
	Southern	3,150	60-40-20	189	126	63
	Total	5,000		300	200	142
1976	Northern	300	60-40-60	18	12	18
	Central	1,920	60-40-60	115	77	77
	Southern	3,780	60-40-20	227	151	76
	Total	6,000		360	240	171
1977	Northern	350	60-40-60	21	14	21
	Central	2,240	60-40-40	134	90	90
	Southern	4,410	60-40-20	265	176	88
	Total	7,000		420	280	199
1978	Northern	400	60-40-60	24	16	24
	Central	2,560	60-40-40	154	102	102
	Southern	5,040	60-40-20	302	202	101
	Total	8,000		480	320	227
1979	Northern	450	60-40-60	27	18	27
	Central	2,880	60-40-40	173	115	115
	Southern	5,670	60-40-20	340	227	113
	Total	9,000		540	360	255
1980	Northern	500	60-40-60	30	20	30
	Central	3,200	60-40-40	192	138	128
	Southern	6,300	60-40-20	378	252	126
	Total	10,000		600	400	284

Table 37. Projected Area, Yield, and Production of Sugarcane, 1971-1980

Year	Area			Yield		Production		
	Total	Fertilized	Nonfertilized	Fertilized	Nonfertilized	Fertilized	Nonfertilized	Total
		ha		mt/ha		1,000 mt		
1971	24,000	500	23,500	80	35	40	822	862
1972	24,000	1.000	23,000	80	35	80	805	885
1973	24,000	1,500	22,500	80	35	120	788	908
1974	24,000	2,000	22,000	80	35	160	770	930
1975	24,000	3,000	21,000	80	35	240	735	975
1976	24,000	3,500	20,500	85	35	298	718	1,016
1977	24,000	4,000	20,000	85	35	340	700	1,040
1978	24,000	4,500	19,500	85	35	382	682	1,064
1979	24,000	5,000	19,000	90	35	450	556	1,115
1980	24,000	5,500	18,500	90	35	495	648	1,143

PROJECTED FERTILIZER NEEDS BY AGRICULTURAL ZONE

In order to project future needs of fertilizer on an area basis, some procedure must be designed to estimate zones of increase or decrease of the different crops. The general guidelines employed in the projections of tables 27-41 are of two types: uniform growth and expansion in direct proportion to current distribution among departments, and disproportionate expansion of selected crops within departments. Wheat-soybeans are the crops in which the biggest area expansion will occur and it is assumed that future growth will continue in the areas of greatest potential for mechanization. Since the current distribution of wheat-soybean hectarage among departments already reflects the growth due to mechanization, expansion of this distribution trend is reasonable. Currently, wheat-soybean areas are fairly evenly divided among the northern, central, and southern sections of eastern Paraguay.

The hectarage expansion in tobacco and rice also is projected on a direct proportion model. Corn, cotton, and sugarcane are not projected for expansion but rather as a substitution of some fertilized hectarage for nonfertilized hectarage. The direct proportion growth rate therefore applies to these.

Projection for fertilizer use in tree crops is relatively small but some localization of expansion may occur. The northern agricultural zone is projected to absorb half the fertilizer, mostly for coffee, with the other half divided evenly between the central and southern agricultural zones. All of the forage fertilization is projected for the central agricultural zone, this being the area where the most intense production of forage for dairy herd maintenance will be required.

Irrigation is used to protect coffee from frost.

PROJECTED FERTILIZER NEEDS BY TYPES

There are two major factors in Paraguay that restrict the type of fertilizer that can be used. These are the high relative humidity during much of the year and the extreme acidity of the soil. Where paddy rice is grown, there is a third restriction.

The high relative humidity causes hygroscopic fertilizers, chiefly nitrogenous materials, to cake readily. Caking is not a problem when such materials are contained in moisture-proof bags. When these materials are handled in bulk, they must be coated with a conditioner. At present, there is some question whether urea can be conditioned adequately to withstand prolonged exposure to high humidity.

Table 38. Projected Corrective and Annual Nutrient Needs for Sugarcane Production, 1971-1980

Year	Type of fertilization	Area to be fertilized	Rate of application (N-P_2O_5-K_2O)	Total nutrients N	P_2O_5	K_2O
		ha	kg/ha		mt	
1971	Corrective	500				
	Northern zone	25	0-120-80	0	3	2
	Central zone	380	0-120-60	0	46	23
	Southern zone	95	0-120-40	0	11	4
	Annual	500	100-50-65	50	25	32
	Total			50	85	61
1972	Corrective	500				
	Northern zone	25	0-120-80	0	3	2
	Central zone	380	0-120-60	0	46	23
	Southern zone	95	0-120-40	0	11	4
	Annual	1,000	100-50-65	100	50	65
	Total			100	110	94
1973	Corrective	500				
	Northern zone	25	0-120-80	0	3	2
	Central zone	380	0-120-60	0	46	23
	Southern zone	95	0-120-40	0	11	4
	Annual	1,500	100-50-65	150	75	98
	Total			150	135	127
1974	Corrective	500				
	Northern zone	25	0-120-80	0	3	2
	Central zone	380	0-120-60	0	46	23
	Southern zone	95	0-120-40	0	11	4
	Annual	2,000	100-50-65	200	100	130
	Total			200	160	159
1975	Corrective	1,000				
	Northern zone	50	0-120-80	0	6	4
	Central zone	760	0-120-60	0	92	46
	Southern zone	190	0-120-40	0	22	8
	Annual	3,000	100-50-65	300	150	195
	Total			300	270	253
1976	Corrective	500				
	Northern zone	25	0-120-80	0	3	2
	Central zone	380	0-120-60	0	46	23
	Southern zone	95	0-120-40	0	11	4
	Annual	3,500	120-55-80	420	192	280
	Total			420	252	309
1977	Corrective	500				
	Northern zone	25	0-120-80	0	3	2
	Central zone	380	0-120-60	0	46	23
	Southern zone	95	0-120-40	0	11	4
	Annual	4,000	120-55-80	480	220	320
	Total			480	280	349
1978	Corrective	500				
	Northern zone	25	0-120-80	0	3	2
	Central zone	380	0-120-60	0	46	23
	Southern zone	95	0-120-40	0	11	4
	Annual	4,500	120-55-80	540	248	360
	Total			540	308	389
1979	Corrective	500				
	Northern zone	25	0-120-80	0	3	2
	Central zone	380	0-120-60	0	46	23
	Southern zone	95	0-120-40	0	11	4
	Annual	5,000	120-55-80	600	275	400
	Total			600	335	429
1980	Corrective	500				
	Northern zone	25	0-120-80	0	3	2
	Central zone	380	0-120-60	0	46	23
	Southern zone	95	0-120-40	0	11	4
	Annual	5,500	120-55-80	660	302	440
	Total			660	362	469

Table 39. Projected Area to be Fertilized and Fertilizer Requirements for Vegetables, 1970-1981[a]

Year	Fertilized area	Rate of application (N-P_2O_5-K_2O)	Total nutrients N	P_2O_5	K_2O
	ha	kg/ha		mt	
1971	3,000	80-80-80	240	240	240
1972	4,000	80-80-80	320	320	320
1973	5,000	100-100-100	500	500	500
1974	6,000	100-100-100	600	600	600
1975	7,000	120-120-120	840	840	840
1976	8,500	120-120-120	1,020	1,020	1,020
1977	10,000	120-120-120	1,200	1,200	1,200
1978	11,500	120-120-120	1,380	1,380	1,380
1979	13,000	120-120-120	1,560	1,560	1,560
1980	15,000	120-120-120	1,800	1,800	1,800

[a]Includes onions, tomatoes, potatoes, sweet potatoes, squash, cabbage, lettuce, carrots, peppers, parsley, and garlic.

Acid soils broaden the spectrum of phosphate fertilizers that can be used satisfactorily but restrict the physical size of particles and method of application. Phosphates with a relatively low content of water-soluble phosphorus, such as the nitric phosphates and the carbonate-substituted apatites (francolites), are satisfactory on acid soils. For effective results, these materials must be nongranular and should be applied broadcast. Most phosphates on the world market, however, contain high amounts of water-soluble phosphorus. For maximum agronomic effectiveness on acid soils, these fertilizers should be applied in granular form. Nongranular forms should be applied in bands in the soil (32). Acid soils have little, if any, effect on nitrogenous fertilizers. Only when soils are neutral to alkaline is there a significant loss of nitrogen from surface application of ammonia-type nitrogen fertilizers.

Potassium leaches more readily from acid soils than from neutral to alkaline soils. The form of potassium applied in fertilizers cannot be changed and so liming of acid soils is helpful. However, leaching conditions prevail for only a small part of the year in eastern Paraguay.

For paddy rice, the ammonium form of nitrogen is more efficient than the nitrate form when the fertilizer is incorporated into the soil. Both urea and ammonium sulfate, then, are superior to ammonium nitrate. If the nitrogen is topdressed on growing plants, however, nitrogen sources are not as critical and ammonium nitrate is as effective as other forms of nitrogen (32).

Table 40. Projected Area to be Fertilized and Fertilizer Requirements for Tree Crops[a]

Year	Fertilized area	Rate of application (N-P_2O_5-K_2O)	Total nutrients N	P_2O_5	K_2O
	ha	kg/ha		mt	
1971	1,000	100-100-100	100	100	100
1972	1,250	100-100-100	125	125	125
1973	1,500	100-100-100	150	150	150
1974	1,725	100-100-100	175	175	175
1975	2,000	120-120-120	240	240	240
1976	2,250	120-120-120	270	270	270
1977	2,500	120-120-120	300	300	300
1978	2,750	120-120-120	330	330	330
1979	3,000	120-120-120	360	360	360
1980	3,500	120-120-120	420	420	420

[a]Primarily coffee and citrus.

Table 41. Projected Area to be Fertilized and Fertilizer Requirements for Forages[a]

Year	Fertilized area	Rate of application[b] (N-P_2O_5-K_2O)	Total nutrients N	P_2O_5	K_2O
	ha	kg/ha		mt	
1971	100	20-50-50	2	5	5
1972	200	30-60-60	6	12	12
1973	400	40-80-80	16	32	32
1974	800	50-100-100	40	80	80
1975	1,200	60-120-120	72	144	144
1976	1,600	60-120-120	96	192	192
1977	2,000	60-100-140	120	200	280
1978	2,500	60-100-140	150	250	350
1979	3,000	60-80-160	180	240	480
1980	3,500	60-80-160	210	280	560

[a]Considers alfalfa and grass forages for dairy operations.
[b]Low level of nitrogen assumes emphasis will be given to alfalfa. Crop removal of phosphorus is considerable less than potassium and the shift to maintenance fertilizer formulas higher in potassium will occur for fields remaining in alfalfa for long periods.

Table 42. Summary of Projected Fertilizer Needs by Crop, 1971-1980

Year	Nutrient	Wheat-soybeans	Corn	Vegetables	Cotton	Rice	Sugarcane	Tobacco	Tree crops	Forages	Total
							mt				
1971	N	1,500	160	240	80	60	50	75	100	2	2,267
	P_2O_5	4,125	320	240	160	40	85	120	100	5	5,195
	K_2O	2,647	221	240	109	29	61	148	100	5	3,560
1972	N	1,950	320	320	160	120	100	100	125	6	3,201
	P_2O_5	2,362	400	320	200	80	110	160	125	12	3,769
	K_2O	1,918	331	320	164	57	94	198	125	12	3,219
1973	N	2,400	480	500	240	180	150	125	150	16	4,241
	P_2O_5	2,700	480	500	240	120	135	200	150	32	4,557
	K_2O	2,256	441	500	219	85	127	248	150	32	4,058
1974	N	3,000	640	600	320	240	200	150	175	40	5,365
	P_2O_5	3,450	560	600	280	160	160	240	175	80	5,705
	K_2O	2,860	551	600	274	113	159	298	175	80	5,110
1975	N	3,750	800	840	400	300	300	200	240	72	6,902
	P_2O_5	4,312	140	840	320	200	270	320	240	144	7,286
	K_2O	3,572	661	840	329	142	253	396	240	144	6,577
1976	N	5,260	1,300	1,020	600	360	420	250	270	96	9,566
	P_2O_5	5,250	945	1,020	390	240	252	400	270	192	8,959
	K_2O	4,510	1,011	1,020	444	171	309	496	270	192	8,423
1977	N	6,300	1,600	1,200	700	420	480	300	300	120	11,420
	P_2O_5	6,300	1,080	1,200	435	280	280	480	300	200	10,555
	K_2O	5,412	1,206	1,200	509	199	349	596	300	280	10,051
1978	N	7,350	1,900	1,380	800	480	540	375	330	150	13,305
	P_2O_5	7,050	1,215	1,380	480	320	308	600	330	250	11,933
	K_2O	6,160	1,401	1,380	574	227	389	744	330	350	11,555
1979	N	7,700	2,300	1,560	900	540	600	450	360	180	14,590
	P_2O_5	6,100	1,515	1,560	525	360	335	720	360	240	11,715
	K_2O	5,804	1,716	1,560	639	255	429	892	360	480	12,135
1980	N	8,050	2,800	1,800	1,000	600	660	500	420	210	16,040
	P_2O_5	6,350	1,860	1,800	570	400	362	800	420	280	12,842
	K_2O	6,054	2,097	1,800	704	284	469	992	420	560	13,380

SUMMARY OF PROJECTED FERTILIZER NEEDS

The hectarage projected for fertilization is given for each crop in each year in table 43. By 1980 over 200,000 ha are projected to receive fertilizer. Nearly half the area is in the central zone and a third is in the southern zone. Needs for each of the three major nutrients in 1975 and 1980 are summarized in tables 44 and 45.

PROJECTED NEEDS AND TYPES OF LIMESTONE

Use of lime is a crucial part of the crop improvement and fertilizer use program which is planned for Paraguay. Many of the soils currently in crop production should be limed and a high proportion of the new lands to be brought into production also will require limestone (tables 27-41). Paraguay is fortunate in having ample quantities of limestone located within the three agricultural zones of the country. Development of this resource is absolutely essential if the fertilizer program is to be successful.

Projecting the lime requirements for Paraguay is somewhat difficult because there is only a limited amount of soil acidity and lime requirement information available locally. Gonzalez compared the acidity characteristics of soils of Paraguay with those of North Carolina and found them to be very similar (33). The lime requirement for very acid soils was found to be approximated by multiplying the exchangeable aluminum content by two. The soils of

Table 43. Summary of Crop Area to be Fertilized

Year	Agricultural zone	Wheat	Corn	Vegetables	Tobacco	Cotton	Rice	Sugarcane	Tree crops	Forages	Total
						ha					
1971	Northern	8,400	220	180	270	60	50	25	500	0	9,705
	Central	9,300	1,100	1,980	900	550	320	380	250	100	14,880
	Southern	7,300	680	840	330	390	630	95	250	0	10,515
	Total	25,000	2,000	3,000	1,500	1,000	1,000	500	1,000	100	35,100
1972	Northern	10,920	440	240	360	120	100	50	625	0	12,855
	Central	12,090	2,200	2,640	1,200	1,100	640	760	312	200	21,142
	Southern	9,490	1,360	1,120	440	780	1,260	190	313	0	14,953
	Total	32,500	4,000	4,000	2,000	2,000	2,000	1,000	1,250	200	48,950
1973	Northern	13,440	660	300	450	180	150	75	750	0	16,005
	Central	14,880	3,300	3,300	1,500	1,650	960	1,140	375	400	27,505
	Southern	11,680	2,040	1,400	550	1,170	1,890	285	375	0	19,390
	Total	40,000	6,000	5,000	2,500	3,000	3,000	1,500	1,500	400	62,900
1974	Northern	16,800	880	360	540	240	200	100	875	0	19,995
	Central	18,600	4,400	3,960	1,800	2,200	1,280	1,520	437	800	34,997
	Southern	14,600	2,720	1,680	660	1,560	2,520	380	438	0	24,558
	Total	50,000	8,000	6,000	3,000	4,000	4,000	2,000	1,750	800	79,550
1975	Northern	21,000	1,100	420	720	300	250	150	1,000	0	24,940
	Central	23,250	5,500	4,620	2,400	2,750	1,600	2,280	500	1,200	44,100
	Southern	18,250	3,400	1,960	880	1,950	3,150	570	500	0	30,660
	Total	62,500	10,000	7,000	4,000	5,000	5,000	3,000	2,000	1,200	99,700
1976	Northern	25,200	1,430	510	900	360	300	175	1,125	0	30,000
	Central	27,900	7,150	5,610	3,000	3,300	1,920	2,660	562	1,600	53,702
	Southern	21,900	4,420	2,380	1,100	2,340	3,780	665	563	0	37,148
	Total	75,000	13,000	8,500	5,000	6,000	6,000	3,500	2,250	1,600	120,850
1977	Northern	30,240	1,760	600	1,080	420	350	200	1,250	0	35,900
	Central	33,480	8,800	6,600	3,600	3,850	2,240	3,040	625	2,000	64,235
	Southern	26,280	5,440	2,800	1,320	2,730	4,410	760	625	0	44,365
	Total	90,000	16,000	10,000	6,000	7,000	7,000	4,000	2,500	2,000	144,500
1978	Northern	35,280	22,090	690	1,350	480	400	225	1,375	0	41,890
	Central	39,060	10,450	7,590	4,500	4,400	2,560	3,420	687	2,500	75,167
	Southern	30,660	6,460	3,220	1,650	3,120	5,040	855	688	0	51,693
	Total	105,000	19,000	11,500	7,500	8,000	8,000	4,500	2,750	2,500	168,750
1979	Northern	36,960	2,530	780	1,620	540	450	250	1,500	0	44,630
	Central	40,920	12,650	8,580	5,400	4,950	2,880	3,800	750	3,000	82,930
	Southern	32,120	7,820	3,640	1,980	3,510	5,670	950	750	0	56,440
	Total	110,000	23,000	13,000	9,000	9,000	9,000	5,000	3,000	3,000	184,000
1980	Northern	38,640	3,080	900	1,890	600	500	275	1,750	0	47,635
	Central	42,780	15,400	9,900	6,300	5,500	3,200	4,180	875	3,500	91,635
	Southern	33,580	9,520	4,200	2,310	3,900	6,300	1,045	875	0	61,730
	Total	115,000	28,000	15,000	10,500	10,000	10,000	5,500	3,500	3,500	201,000

eastern Paraguay which have pH 5.0 or lower probably contain an average of 1.5 meq Al^{+3}/100 g soil; therefore, an initial application of 3 mt/ha of limestone can be projected for these soils. On the other hand, soils which have only 0.1-0.2 meq Al^{+3}/100 g soil may require a minimum application of 1.0 mt/ha of limestone to provide an adequate amount of calcium even though less lime is required to neutralize the aluminum (33). Soils with pH 5.1-5.5 probably correspond to this group. Above pH 5.5 no initial lime application is projected. Lime requirement studies have been initiated recently to refine this information (35).

Table 44. Summary of Nutrient Projections, 1975

Crop	Type of fertilization	Northern zone			Central zone			Southern zone			Total		
		N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
							mt						
Wheat-soybeans	Corrective	0	504	336	0	552	276	0	444	148	0	1,500	760
	Annual	1,260	945	945	1,395	1,046	1,046	1,095	821	821	3,750	2,812	2,812
	Subtotal	1,260	1,449	1,281	1,395	1,598	1,322	1,095	1,265	969	3,750	4,312	3,572
Other crops													
Cotton	Corrective	0	7	5	0	66	33	0	47	16	0	120	54
	Annual	24	12	16	220	110	151	156	78	108	400	200	275
Corn	Corrective	0	26	18	0	132	66	0	82	27	0	240	111
	Annual	88	44	60	440	220	302	272	136	188	800	400	550
Sugarcane	Corrective	0	6	4	0	92	46	0	22	8	0	120	58
	Annual	15	8	9	228	114	148	57	28	38	300	150	195
Tobacco	Annual	36	58	86	120	192	240	44	70	70	200	320	396
Rice	Annual	15	10	15	96	64	64	189	126	63	300	200	142
Vegetables	Annual	50	50	50	554	554	554	236	236	236	840	840	840
Tree crops	Annual	120	120	120	60	60	60	60	60	60	240	240	240
Forages	Annual	–	–	–	72	144	144	–	–	–	72	144	144
	Subtotal	348	341	383	1,790	1,748	1,808	1,014	885	814	3,152	2,974	3,005
Total		1,608	1,790	1,664	3,185	3,346	3,130	2,109	2,150	1,783	6,902	7,286	6,577

Table 45. Summary of Nutrient Projections, 1980

Crop	Type of fertilization	Northern zone			Central zone			Southern zone			Total		
		N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
							mt						
Wheat-soybeans	Corrective	0	204	136	0	216	108	0	180	60	0	600	304
	Annual	2,705	1,932	1,932	2,995	2,139	2,139	2,350	1,679	1,679	8,050	5,750	5,750
	Subtotal	2,705	2,136	2,068	2,995	2,355	2,247	2,350	1,859	1,739	8,050	6,350	6,054
Other crops													
Cotton	Corrective	0	7	5	0	66	33	0	47	16	0	120	54
	Annual	60	27	39	550	248	358	390	175	253	1,000	450	650
Corn	Corrective	0	66	44	0	330	165	0	204	68	0	600	277
	Annual	308	139	200	1,540	693	1,001	952	428	619	2,800	1,260	1,820
Sugarcane	Corrective	0	3	2	0	46	23	0	11	4	0	60	29
	Annual	33	15	22	502	230	334	125	57	84	660	302	440
Tobacco	Annual	90	144	216	300	480	600	110	176	176	500	800	992
Rice	Annual	30	20	30	192	128	128	378	252	126	600	400	284
Vegetables	Annual	108	108	108	1,188	1,188	1,188	504	504	504	1,800	1,800	1,800
Tree crops	Annual	210	210	210	105	105	105	105	105	105	420	420	420
Forages	Annual	–	–	–	210	280	560	–	–	–	210	280	560
	Subtotal	839	739	876	4,587	3,794	4,495	2,564	1,959	1,955	7,990	6,492	7,326
Total		3,544	2,875	2,944	7,582	6,149	6,742	4,914	3,818	3,694	16,040	12,842	13,380

Initial lime requirements for the country are projected for each of the three agricultural zones on the basis of the soil test summary in table 3. The weighted mean lime requirement for the northern, central, and southern zones is 1.20, 1.08, and 1.03 mt/ha, respectively. These weighted means apply to all newly fertilized hectarage, as given in tables 27-41.

Following the initial application, maintenance applications are necessary. Again, there is not much information available locally regarding the rate of lime necessary to

maintain a satisfactory rooting environment. However, liming studies on soils of North Carolina indicate that from 1 to 3 mt/ha of limestone is required every 3 or 4 years, depending on soil characteristics and rates of nitrogen fertilizer employed (43).

The amount of acidity which arises from nitrogen varies with the type of fertilizer used, but usually it is considered that 5.35 kg of $CaCO_3$ is required to chemically neutralize the acidity produced by 1.0 kg of applied nitrogen. If a factor of 1.5 is used to go from chemical neutralization to effective neutralization in the soil (42), an annual maintenance of about 8 kg of lime is needed for each 1 kg N/ha. Table A-6 summarizes the amount of limestone which would be required to neutralize the range of nitrogen applications projected for the various crops to be fertilized.

Maintenance lime projections in table A-7 are based on application of limestone every 3 years. A distinction was made between wheat and other crops when making the maintenance limestone projections. Since wheat mostly will be grown on sandy, low cation-exchange capacity soils, a maintenance limestone requirement of 1.5 mt/ha every 3 years was projected. This rate coincides rather closely with the acidity produced due to nitrogen fertilizer (table A-6). The remaining crops will predominately be grown on soils with a higher clay content and the average rate of nitrogen fertilization also will be higher. Therefore, it was assumed that an average of 2.5 mt/ha every 3 years would be a reasonable maintenance application rate to use for the projections on these crops.

It should be emphasized at this point that, as in the case of the rates of fertilizers, the projection rates are not recommended rates to be used as general formulas. Specific recommendation rates for crops and soils must be made on the basis of soil tests and the most current research information available at the time. The projection rates merely provide a means of predicting the total needs which will be required in different parts of the country over the projection period.

For the projections in table A-7, calculations were made as follows. For the year 1971, all hectarage to be fertilized was scheduled into the lime program with an "initial" application of lime. In subsequent years, only new land added to the fertilizer program was scheduled to receive an initial application of lime. In 1974, 3 years after the start of the lime program, maintenance applications were started. By 1977, some soils were ready for their second maintenance application of lime, some were ready for their first maintenance application, and, of course, some were receiving an initial application. In 1980 these same soils were scheduled to receive a third, a second, and a first maintenance application respectively.

Lime projections, by year and by agricultural zone, are summarized in table 46. By 1980, annual lime needs will be over 150,000 mt of agricultural lime. Every third year, of which 1980 is an example, the requirement bulges due to the catchup program that started in 1971. Normally, one-third of the soils should be limed each year.

The projections in tables 46 and A-7 are based on limestone of 100% neutralizing effectiveness. That is, the limestone is considered to be pure calcite ground finely enough to react completely in 3 years or less. If limestone of poorer or better quality is used, the projections must be adjusted up or down accordingly.

No distinction has been made in the projections for calcitic versus dolomitic limestone. Both types of stone are available in Paraguay but information simply is not available to recommend how much of each material should be used in any particular location. Undoubtedly, many soils are low in both calcium and magnesium. For such soils, dolomite would be preferred providing its cost did not exceed that of calcite plus magnesium fertilizer. For many soils, the problem is acidity *per se* and the type of limestone used to correct the acidity is not important.

Table 46. Summary of Projected Limestone Needs, 1971-1980 (from table A-7)

Year	Agricultural zone			Total
	Northern	Central	Southern	
		mt		
1971	11,646	16,070	10,830	38,546
1972	3,780	6,763	4,571	15,114
1973	3,780	6,872	4,570	15,222
1974	20,650	35,991	24,311	80,952
1975	11,289	22,696	15,190	49,175
1976	11,427	23,488	15,584	50,499
1977	29,558	54,286	36,422	120,266
1978	20,706	42,778	28,058	91,542
1979	17,093	40,856	26,361	84,310
1980	35,794	73,063	48,099	156,956

Section VI

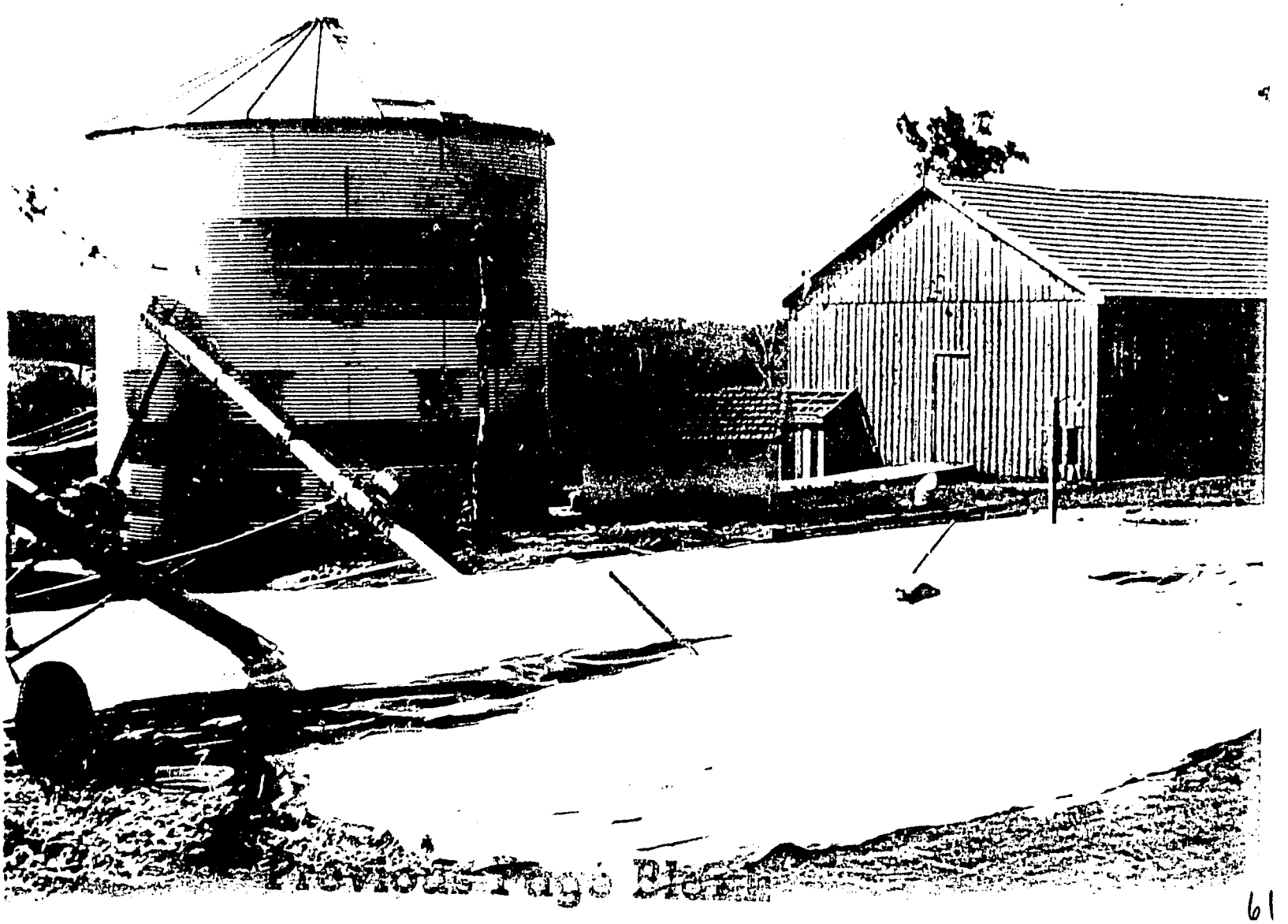
RECOMMENDATIONS FOR MEETING LIME AND FERTILIZER NEEDS

INTRODUCTION

So far this report has been concerned with the marshalling of the data and background information needed for the study objectives given in section II. Small amounts of fertilizer have been used for several years but in the last two years use has increased greatly. Another important feature is that Paraguayan agricultural leaders are committed to a program of reducing imports and increasing exports. Expanded production of particular crops is fundamental to the program, and lime and fertilizer use clearly must be an integral part of expanded production.

Wheat is a crucial crop. Presently 30,000-40,000 ha is planted but only about half the area is fertilized. At least a fivefold expansion in fertilized hectarage would be required to reach self-sufficiency. About 40,000 mt of fertilizer and nearly 65,000 mt of agricultural lime would be needed annually for this much wheat. To increase lime and fertilizer use to this magnitude creates many problems in procurement, handling, and use. These problems must be solved successfully if there is to be any chance of materially decreasing the price of fertilizer, initiating an agricultural limestone industry, or making any very significant strides in agricultural development. No other crop has the potential

Wheat is a crucial crop in expanding the use of fertilizer.



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for using as much lime and fertilizer and producing as much profit as wheat.

If the wheat program fails, then fertilizer use can expand only on those crops already produced in sufficiency or surplus. Production in excess of actual needs usually reduces the price of the product and decreases the profitability of fertilization. While the excess could be exported on the world market, this means competition with similar products produced in countries with seaports and lower marketing costs.

Success in a wheat program would lead to advances in other areas of agricultural production. Expanded use of fertilizer permits economies in purchase and innovations in handling which decrease price to the farmer. Each decrease in price permits fertilizer use to be extended to more and more crops. In most cases, use of fertilizer reduces the unit cost of production so that farmers gain more net profit.

Wheat has additional characteristics that are of real advantage in developing a fertilizer program. It is a fall-planted crop whereas most other crops are spring-planted. Thus, there are two seasons of the year when fertilizer can be used. This is advantageous because it makes fertilizer more nearly a year-round business. Storage and handling facilities can be used more efficiently and companies can afford to train salesmen more thoroughly because they are more likely to be permanent employees. In the past, most fertilizer has been used in the spring on crops other than wheat. As the wheat program develops, percentage use of fertilizer will shift strongly to fall and then slowly revert to almost equal use in the spring and fall. Table 47 shows that fertilizer needs for the country are almost equally divided between fall and spring or wheat versus all other crops. (There may be some exceptions to these generalized observations. For example, some wheat will be topdressed with nitrogen in the spring, particularly in the higher rainfall areas. Furthermore, it is assumed that tree crops may be fertilized in the fall. However, the exceptions to the rule counterbalance each other and therefore, for convenience, wheat is categorically described as a fall-fertilized crop and all others as spring-fertilized.) Among the agricultural zones, the ratio between fall and spring shifts slightly and also changes with time. Fall fertilizer needs are almost equally divided among the three agricultural zones but spring needs are concentrated in the central and southern zones.

The importance of the package approach to crop production cannot be stressed too strongly. No one part of the package—quality seed, use of fertilizer, timely planting and harvesting, adequate credit, etc. is considered as more important than any other part. In Paraguay use of agricultural limestone must also be considered an integral part of the package. For example, wheat in 1970 ranged from excellent to poorly tillered thin stands to barren spots. Some of the poor wheat could be attributed to improper planting, disease and insects, and low quality seed. In many cases, however, the wheat appeared to be deficient in phosphorus, despite applications of phosphate fertilizer. Apparently, phosphorus applied to acid soils was fixed by soil minerals so quickly and so tightly that plants could not absorb the quantities necessary to tiller and grow properly. In some cases, the soil was too acid even for the seed to germinate. These situations were not confined to any one agricultural zone. No amount of investment in seed, fertilizer, or irrigation equipment will overcome the basic difficulty of soils that are too acid. Only use of limestone will correct this problem. Thus, agricultural limestone is considered essential to wheat production, wheat production is considered essential to agricultural development, and agricultural development is considered essential to the economy of the country.

In the discussions that follow, several alternatives are considered for obtaining lime and fertilizer for Paraguay. The principal criterion here has been cost to the farmer. Production of agricultural limestone is rather straightforward because of the lime deposits in various areas of the country. Distribution is not as simple because there are no known dolomite deposits in the central agricultural zone. The fertilizer situation is even more complicated. The alternatives considered were manufacture of phosphate within Paraguay, purchase of bagged or bulk fertilizer on the world market, and importation by various routes.

AGRICULTURAL LIMESTONE PRODUCTION

Paraguay has a long history of producing crops without using agricultural lime even though limestone outcrops in most of the agricultural areas. If crop production is to be accelerated through use of fertilizer and other good husbandry practices, use of lime becomes essential. Calcined limestone, CaO, already is made for the construction

Table 47. Projected Fertilizer Needs[a]

Agricultural zone	Crop	Fertilizer needs 1975	1980
		mt	
Northern	Wheat	8,585	16,990
	All others	2,403	5,685
Central	Wheat	9,344	18,736
	All others	12,080	30,511
Southern	Wheat	7,222	14,667
	All others	6,462	16,074
Total	Wheat	25,151	50,393
	All others	20,945	52,270
	Total	46,096	102,663

[a]Plant nutrient needs (table 44) converted into fertilizer needs using ammonium sulfate (21-0-0), diammonium phosphate (18-46-0), and muriate of potash (0-0-60) as the nutrient sources.

industry. It could be used for specialty agriculture and very small fields. Wide-scale use, however, creates problems that do not have economical solutions. That is, exposure of calcined lime to the atmosphere results in absorption of water to form hydrated lime, $Ca(OH)_2$. Simultaneously, the material becomes lumpy so that it cannot be applied uniformly without recrushing. Hydration can be prevented by bagging the lime in waterproof bags. One kiln operator, Marcelo Casanas, in the Coronel Oviedo-Caaguazu area, follows this practice—crushing burned lime, sieving it through a 100-mesh screen, and packaging in 50-kg bags. Production rate is about 1 mt/hour. Calcium oxide is satisfactory for the man who needs only a bag or two of lime. (CaO is almost twice as effective as ground limestone, $CaCO_3$, and thus is applied at about half the rate per hectare as ground limestone.) For large fields, bagged limestone is too expensive. A more economical alternative involves grinding lime rock and handling it in bulk. Ground raw limestone, $CaCO_3$, does not react with water and become lumpy. However, grinding lime rock requires an investment in machinery that is not necessary for the production of calcined lime. Ground limestone also should meet various specifications before it is sold for use as a liming material. These specifications should not be so rigid that cost of production prevents profitable use of lime.

Production Specifications

The quality of limestone is determined by two characteristics—fineness of grinding and chemical composition. The two are not independent of one another because dolomitic limestone dissolves in the soil at about half the rate as calcitic limestone when particle sizes are the same.

There is no universal agreement on the particle fineness needed for agricultural lime. Generally, a range of sizes is suggested in order that some of the lime will dissolve immediately to neutralize soil acidity and some will dissolve as much as 2-4 years later. The ASTM uses two screens, 8-mesh and 60-mesh, to evaluate limestone quality (5). (Mesh number indicates the number of sieve wires per lineal inch or per 2.54 cm; thus, an 8-mesh screen has 8 wires/inch and the apertures are 0.0937 inches or 2.25 mm square.) Material too coarse to pass the 8-mesh sieve has so little neutralizing value in the soil that it is considered of no value. Material 60 mesh and finer in size dissolves almost completely during the first year after application. The society recognizes five classes of lime on the basis of the percentage of material that does or does not pass through the two screens. Barber (20) has summarized the effect of particle sizes on crop yields for a large number of crops and soils in the United States. His summary is shown in table 48. Codas (24) based his evaluation of Paraguayan limestone on Illinois information, as given in table 49.

Table 48. Effect of Particle Size of Limestone on Relative Crop Yields (20)

Particle size	Relative yield	
mesh no.	average	range
4-10	33	0-50
10-20	54	11-96
20-40	84	34-100
40-80 or 40-100	99	61-100
80+ or 100+	100	78-100

Table 49. Comparative Value of Various Lime Fractions 1, 4, and 8 Years after Application (24)

	Number of years after application		
Size of fraction	1	4	8
mesh no.	relative value		
< 60	100	100	100
30-60	50	100	100
9-30	20	45	75
> 9	5	15	25

Crushing machinery normally will produce a range of particle sizes even though the limestone is crushed to pass only a single screen of fairly coarse mesh. Barber, summarizing data on 244 limestone samples from various U.S. quarries, obtained the results shown in table 50 (20).

We recommend that initial specifications for particle fineness of agricultrual limestone be as follows: 100% through 8-mesh and 50% through 60-mesh screens. Laboratory, greenhouse, and field studies with Paraguayan limestones used under Paraguayan conditions, when available, should be used to refine this recommendation.

Chemical composition is equal in importance to fineness of grinding in affecting the liming value of agricultural lime. According to Beacher *et al.*, dolomite reacts in the soil only about half as fast as calcite (21). The data are shown in table 51. It is not necessary, however, to grind dolomite to a finer size than calcite. Most quarries yield a mixed stone rather than a pure dolomite. Thus, Vallemi stone consists of 60%-65% dolomite and 20%-30% calcite (table 18). The Villa Florida deposit of dolomite also contains up to 30% calcite (table 22). Thus, grinding to the size recommended above still is satisfactory. The fine calcite portion will react quickly to neutralize acidity. The dolomite and coarser calcite will form the slower-acting reserve.

Dolomite does have a greater effect than calcite, per unit of weight. The best liming material, as mentioned earlier, is calcined lime. A comparison of various liming materials is given in table 52.

Limestone deposits rarely are pure calcite or dolomite or even mixtures of the two. Other minerals with no liming value, such as quartz, illite, feldspar, mica, etc., invariably are present in the deposit (tables 16-22). So also are

Table 50. Average Particle Size Distribution of Commercial Limestones Ground to Different Fineness (20)

Percentage passing	Percentage distribution among size fractions				
60 mesh	4-10 mesh	10-20 mesh	20-40 mesh	40-90 mesh	90+ mesh
15	40	35	7	8	10
20	20	25	21	14	20
35	15	25	18	17	25
45	5	23	17	20	35
55	2	14	16	20	48
75	0	8	10	20	62

Table 51. Effect of Particle Size on the Relative Effectiveness of Calcite and Dolomite (21)

Size fraction	Calcite	Dolomite
mesh no.	relative value	
20-60	19	11
60-100	50	25
100-200	85	39
< 200	99	60

Table 52. Neutralizing Value of Various Liming Materials

Liming material	Chemical formula	Relative neutralizing value
Calcined lime	CaO	179
Hydrated lime	$Ca(OH)_2$	136
Dolomite	$CaMg(CO_3)_2$	109
Calcite	$CaCO_3$	100
Calcium silicate	$CaSiO_3$	86

weathering products from the overburden and even some of the sand and silt overburden itself that have moved down into fractures (sample 11, table 16). The limestone deposits in east-central Paraguay are described as thinly bedded limestone separated by layers of clay. Lenticular oolitic nodules of silica are contained within the limestone. Some of this clay and silica will unavoidably be included in agricultural limestone. Liming value will be reduced accordingly. All limestone quarries in Paraguay have an overburden of varying thickness. Good quarry management requires that the overburden be removed before rock is quarried but removal of the overburden adds to the cost of quarrying. Failure to remove all the overburden, either deliberately or through poor management, rapidly reduces the quality of the lime. This reduction in quality cannot be detected except by chemical tests. Codas (24) found that the neutralizing value of four samples of limestone in Paraguay ranged from 88% to 97% compared to pure calcite. When the average purity of the four samples was combined with the average range of particle sizes, the Paraguayan lime had an effective neutralization power only 54% of that of finely ground, pure calcite.

We recommend that the GOP establish quality standards for agricultural limestone based on both fineness of grinding and purity. Quarry operators can use the standards to establish prices according to the quality of material they are able to produce. Farmers will use the standards to determine the actual quantity of limestone to apply when following soil test recommendations.

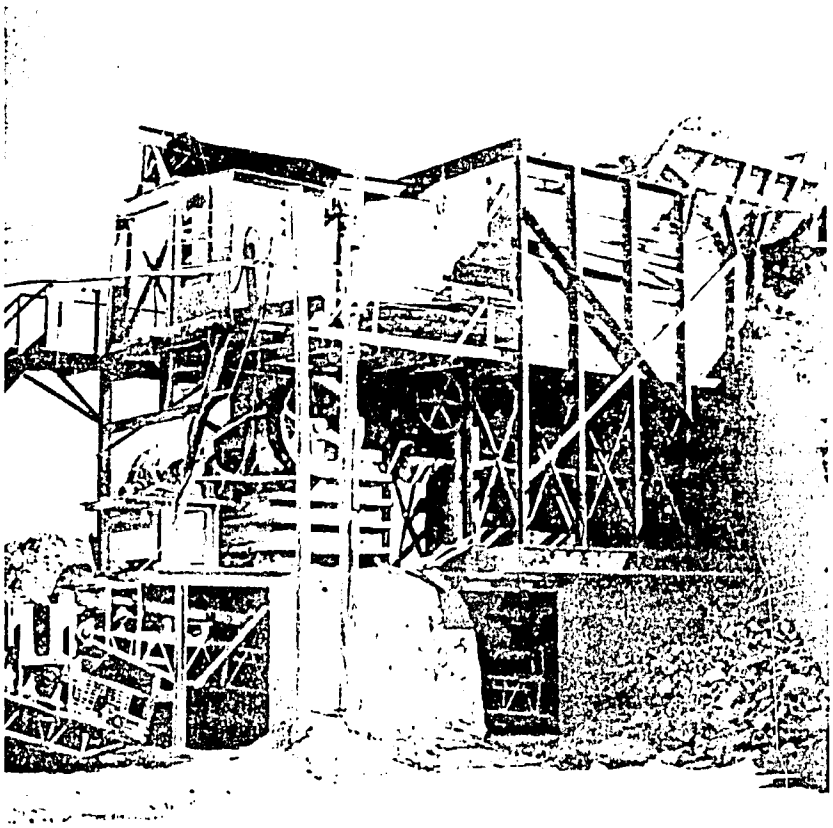
Production Equipment and Costs

In order to produce agricultural lime in the quantity and quality needed, investments must be made in crushers, screens, and other equipment. The minimum equipment needed for each crushing operation consists of a primary crusher, a secondary crusher, screen, conveyor, power unit, and weighing scale. Optional equipment consists of a tractor and loader.

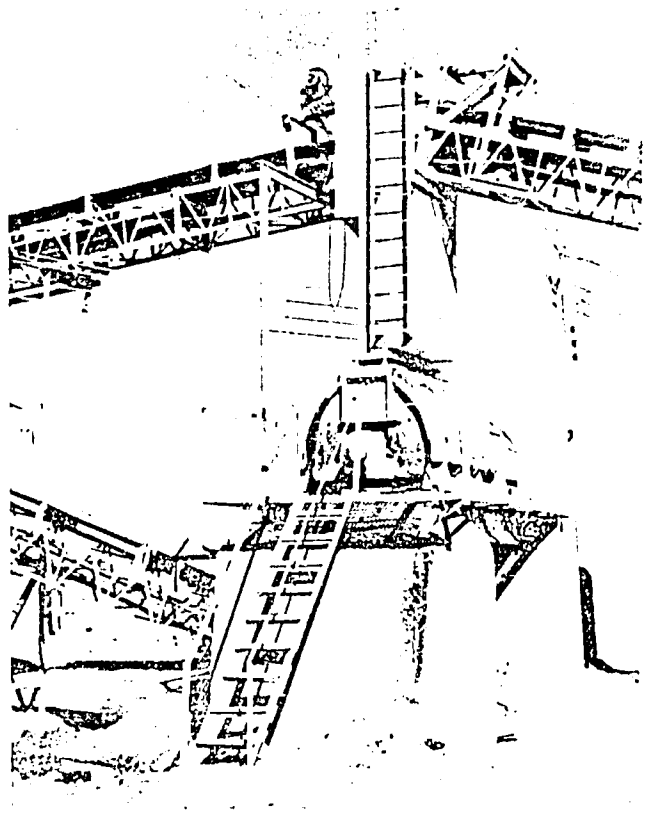
The primary crusher, such as a jaw crusher, is used to reduce large blocks (up to 75 x 100 cm) of stone to material about 3 cm in diameter. This material is fed into the secondary crusher where it is ground into agricultural lime. Three types of grinders can be used as the secondary crusher: ball mill, cage mill, and hammer mill. Ball mills have a low power requirement and need the least maintenance. Both ball and cage mills, however, clog up when the limestone is moist—as often will be the case in Paraguay. Hammer mills are not affected by moisture. Maintenance on hammer mills consists mostly of periodically rebuilding worn hammers.

A double-deck vibrating screen, preferably of stainless steel, is used to separate oversize material from final product. Stainless steel screens do not blind or clog as readily as ordinary steel when the limestone is damp; stainless steel also lasts about three times longer than ordinary steel. The top screen should remove material coarser than 1 cm and return it to the crusher. This saves wear on the more costly and fragile bottom screen. The bottom screen is 8- or 10-mesh; material coarser than this is recycled to the grinder. The grinder is adjusted so that 50% of the particles will be 60-mesh or finer.

The conveyor moves product from the grinder to a stockpile or possibly to a hopper that discharges by gravity



The jaw crusher can be used as a primary crusher to reduce large blocks of stone.



A secondary crusher such as a hammer mill follows the primary crusher.

into a boat or truck. The conveyor also is used to move product from the stockpile into trucks or boats. Thus, it should be portable. None of the quarries are located so that they can use electrical power; therefore, a diesel or gasoline power unit is necessary to run the jaw crusher, grinder, and conveyor.

A tractor and loader is suggested as optional equipment. It is used to load limestone blocks into the jaw crusher. Alternatively, the jaw crusher can be fed by hand labor but blocks would have to be smaller. The tractor and loader also can be used to fill the conveyor hopper with limestone from the stockpile when a truck is being loaded. U.S. sources of equipment are given in table 53.

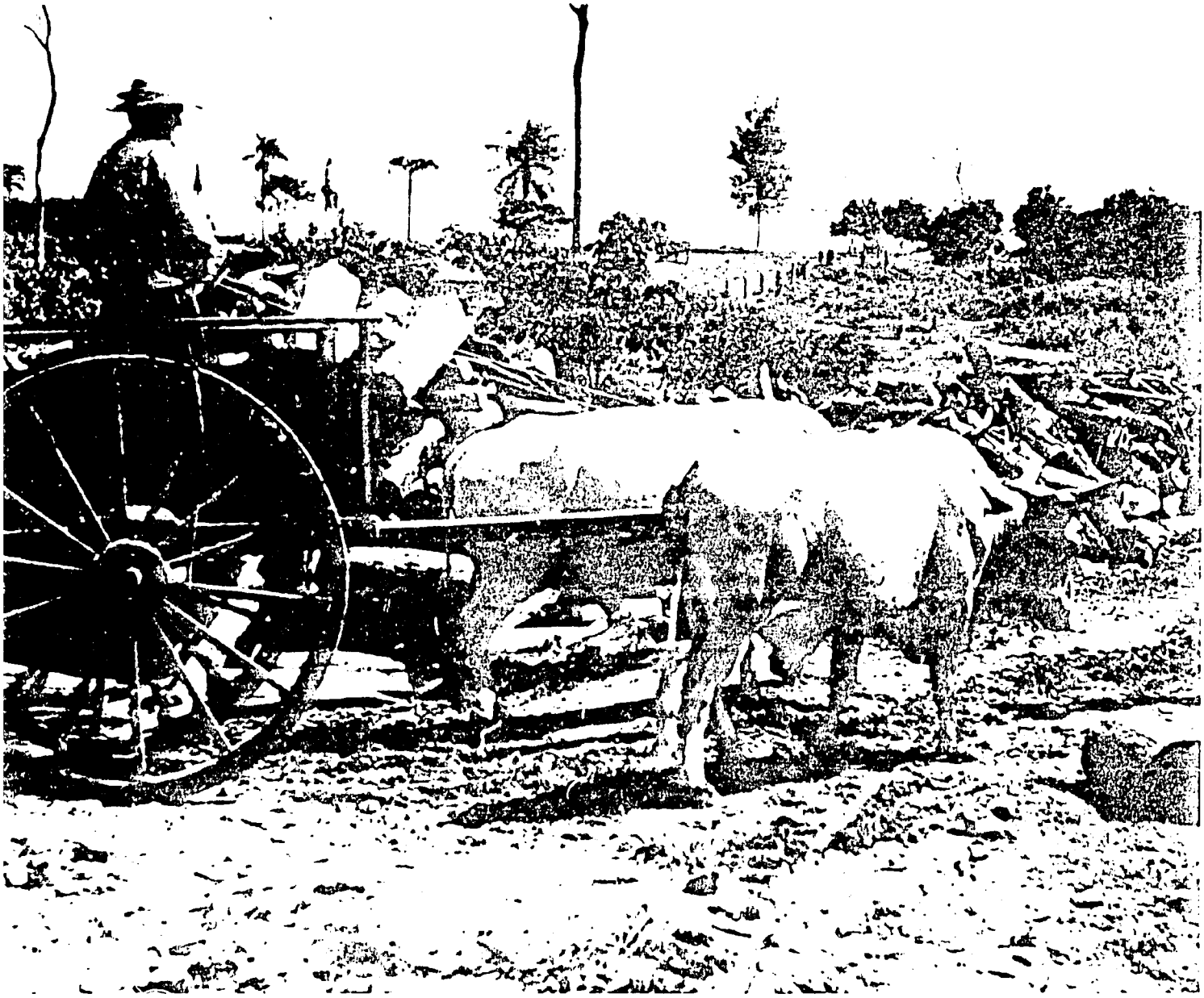
Production of up to 15,000 mt/year for each agricultural zone just about satisfied projected needs through 1976 (table 46). Equipment that will produce 50 mt/day for 300 days/year, then, is about the size that is needed. For some of the northern Paraguay quarries, larger equipment could be justified. For the small quarries in central and southern Paraguay, more than one set of small equipment would be more practical than a single plant with high capacity equipment.

Allowing $1.00/mt for the raw limestone and providing for a 10% return on a plant investment of $92,400, the cost of producing limestone in Paraguay is estimated to be $5.34/mt (table 54). To this production cost must be added administrative costs, sales and marketing expenses, and any transportation costs that are not passed on directly to the purchaser.

Distribution and Marketing

Very little limestone will be used in the immediate vicinity of a quarry. Some type of distribution system is necessary whereby large quantities of lime can be transported in bulk for fairly long distances. As an example, the northern quarries are not at all near a major agricultural area. All product must be transported to a use area. Fortunately, the quarries are located on or very near the Paraguay River so that water transportation to ports serving agricultural areas is practical. The distribution problems peculiar to each of the three agricultural zones and the quarries that can most economically serve them are discussed below. The central zone is discussed first because quarries in this area are most likely to be the first to produce agricultural lime on a commercial scale.

Central Agricultural Zone—The agriculture in this area is scattered along the 327-km International Highway from Asuncion to Puerto Presidente Stroessner. It also extends south from Coronel Oviedo to Villarrica, Caazapa, and Boqueron. The lime quarries are located between Coronel Oviedo and Caazapa or almost exactly half way between Asuncion and Puerto Presidente Stroessner.



Primitive transportation methods mean slow mining operations.

The principal problem is the multiple ownership of the limestone deposits. This generally is an area of small farms and the limestone extends under many of these. Currently, several farmers are quarrying and calcining limestone. It is unlikely that each of these could raise the capital needed to establish a crushing operation nor is it even desirable to have so many crushing units operating so close together. A possible solution is for these farmers to form a cooperative. The cooperative, then, would establish and operate a centrally located crusher. Presumably, the cooperative would contract with each member to deliver so much stone per month or year. Nonmembers might or might not be eligible to sell stone to the crusher but certainly should be permitted to purchase agricultural lime.

An alternative is for some entrepreneur to establish a crushing operation and to obtain the stone by purchase or lease of mineral rights. Essentially, this is what is happening in the area. At the time of the TVA survey, SOFIN, SRL already had mining rights to several million tons of limestone. Mineable stone is estimated to be sufficient to last for nearly 50 years at the contemplated 15,000 mt/year mining rate. As table 46 shows, however, annual needs in the central area will be 3-4 times larger than 15,000 mt/year by 1980. Whether it would be more economical to install equipment with a higher capacity or to establish a second crusher at another location cannot be evaluated now. A more detailed map of the size and location of mineable deposits in the area is needed.

The central quarries most likely will be the first in the country to produce agricultural limestone. They may also be the only source of lime for the entire country for two or more years. Distribution thus becomes a rather formidable

Table 53. Equipment Sources for Production of Agricultural Limestone

Pennsylvania Crusher Corp.
Subsidiary of Both Industries, Inc.
Box 100J
Broomall, Pennsylvania 19008

Jeffrey Manufacturing Company
956 N. Fourth Street
Columbus, Ohio 43216

Williams Patent Crusher & Pulverizer Co.
807 Montgomery Street
St. Louis, Missouri 63102

Iowa Mfg. Co.
916 16th N.E.
Cedar Rapids, Iowa 42400

Portec, Inc.
Pioneer Division
3200 Como Avenue, S.E.
Minneapolis, Minnesota 55400

American Pulverizer & Crusher Co.
1249 Macklind Avenue
St. Louis, Missouri 63100

Universal Road Machinery Co.
Emerick & Shufeldt Streets
Kingston, New York 12401

Lima Plant Construction
Equipment Division
Main & Willis Streets
Lima, Ohio 45800

Smith Engineering Works Division
of Barber-Green Co.
516 E. Capitol Drive
Milwaukee, Wisconsin 53200

Table 54. Estimated Capital, Variable, and Fixed Costs for Agricultural Limestone Production

Capacity		
15,000 mt/yr or		
50 mt/day for 300 days/yr		
Capital Investment		
Plant[a]	$ 92,400	
Working capital[b]	23,775	
Total	$116,175	
Variable Costs		*$/mt*
Limestone		1.00
Diesel fuel		.10
Product loss		.11
Total variable cost		1.21
Fixed Costs		
Operating labor[c]		1.03
Maintenance, 5% of plant investment		.30
Analyses, 10% of operating labor		.10
Overhead, 100% of operating labor		1.03
Insurance, 2% of plant investment		.12
Depreciation, (10 years)[d]		.62
Return on investment, 10% of plant investment		.62
Interest on working capital, 8%[e]		.06
Interest on plant investment, 8%[e]		.25
Total fixed cost		4.13
Total cost of production		5.34

[a]Plant costs:

Jaw crusher	$10,000
Hammer mill	10,000
Double-deck screens	7,000
Conveyor	9,000
Portable generator	22,000
Truck scales	8,000
Subtotal	66,000
Delivery & installation, 40% of equipment cost	26,400
Total	$92,400

[b]Equivalent to the cost of raw materials for one month plus the value of production for three months.

[c]Labor:

1 supervisor @ $250/month	=	$ 250
3 operators @ $75/month	=	225
4 laborers @ $60/month	=	240
Cost/month		715
Fringe benefit, 80%		572
Total cost/month		1,287
Annual cost		15,444
Cost/mt limestone		1.03

[d]The depreciation on crushing equipment is based on 10 years, rather than the 15 years used for most plants, because of the exposed condition.

[e]Due to amortization, average annual rate is 4%.

problem. Lime need is divided more or less equally among the three agricultural zones although the central zone is projected to use about 40% of the lime (table 46). Lime use is tied intimately to fertilizer use and thus to the National Wheat Program. Most of the large wheat producers are innovators with modern equipment. Many would be able to send trucks to the crusher for a load of lime, especially if the lime were a backhaul for the truck. For these trucks, 10 mt usually constitutes a load. Producers with a thousand or more hectares needing an initial application of 3 mt/ha would need to make 300 or more trips to satisfy their needs. Producers in the Misiones and Pedro Juan Caballero areas are not likely to be able to haul enough lime to treat all their fields.

The crusher operator should consider—as SOFIN, SRL already is—the purchase and operation of 30-mt delivery trucks. Assuming that the average trip to the Pedro Juan Caballero area requires three days, two days to Encarnacion, and one day to either Asuncion or Puerto Presidente Stroessner, three trucks would haul an average of 55 mt/day. About a third of the projected lime needs for 1971 and all for 1972 and 1973 could be met by this

schedule (300 days/year). By 1973 quarries in other areas should be in operation and the three trucks could be used to haul lime in the central zone only. Backhauls of wheat, soybeans, or any other commodity should be arranged as frequently as possible.

Assuming that cost of production is $5.34/mt and that 20% is added for administrative and sales expenses, the cost of the lime at the crusher site is $6.40/mt. Transportation costs are estimated at $0.025/mt/km on asphalt roads and $0.040/mt/km on dirt roads. These rates are based on the average rate for 10-mt trucks with backhaul (table 23). For 30-mt trucks the rate would be at least 25% lower but the lack of backhaul would increase the rate again. Thus, rates are estimated to be about the same as given in table 23. Wheat farmers in the San Juan Bautista area would have to pay about $13/mt for lime delivered to the farm site whereas farmers in the Puerto Presidente Stroessner area would have to pay around $11/mt. Because of the dirt roads, lime delivered to Pedro Juan Caballero would cost nearly $24/mt. (However, see below the discussion on the northern agricultural zone.)

There undoubtedly will be some need for magnesium in the central area. Dolomite usually is considered the least expensive source of this plant nutrient but none has been found in the central area. Dolomitic stone can be supplied from Vallemi or Villa Florida when magnesium is needed. The size of the Villa Florida deposit is not known but this would be the cheaper source. However, the cost of magnesium from dolomite should be compared to the cost of magnesium imported as fertilizer before a purchase decision is made.

We recommend development of the central Paraguayan agricultural lime industry as quickly as possible. SOFIN, SRL has controlling interest in some of the deposits and has initiated plans for producing agricultural lime. The GOP should give this company as much help as possible, such as assisting in establishing the size and location of mineable limestone and assisting in financing the crushing machinery. The company should conduct a thorough market analysis before ordering the crushing machinery, however.

Southern Agricultural Zone—Production of wheat in the Misiones area is the major development scheduled for the southern zone. In addition, there are many other agricultural locales and crops that need lime and fertilizer. The Villa Florida limestone deposit is located near the northern boundary of the area or only 50 km from the heart of the wheat land.

The principal problem is the lack of information concerning the limestone deposit. The only known quarry is located on the banks of the Rio Tebicuary. Either the high watertable or flood overflow had filled the quarry with water at the time of the TVA survey. Neither the extent of the deposit nor the quality of the stone could be determined. As table 22 shows, samples from a kiln stockpile adjacent to the quarry are highly variable in composition ranging from a high of 85% dolomite plus 12.5% calcite to a low of less than 35% magnesian calcite. The relative proportion of low-grade to high-grade rock could not be determined.

This quarry, or others that might be developed nearby, is very important to agricultural progress in southern Paraguay. Transportation charges are reduced almost $6/mt for farmers living south of the quarry if they can purchase lime here rather than at Coronel Oviedo. In fact, any location west and south of Caacupe can be supplied from the Villa Florida quarry at a cost equal or lower than from the quarries east of Coronel Oviedo.

Only a tentative distribution system can be proposed at the present time because so much information is not available. Table 46 shows that lime needs in the southern zone increase from about 11,000 mt in 1971 to 48,000 in 1980. If some of the needs in the western portion of the central zone are included in the Villa Florida marketing area, the first crushing unit should have a production capacity of about 20,000 mt/year or 70 mt/day. In about 1976 a second unit of the same size should be constructed. One 30-mt delivery truck should be adequate for each crushing unit. This truck should average nearly two trips per day because most of the lime needs to be hauled only about 50 km. Furthermore, many of the farmers would be able to haul their own lime from the crusher because of the relatively short haul. Lime cost to most wheat farmers, then, is about $7.65/mt ($6.40 FOB mine plus $1.25 transportation).

We recommend that the GOP investigate the size and quality of the limestone deposits at Villa Florida and any other locations in the southern zone. Private interests should be encouraged and assisted to develop an agricultural lime industry in southern Paraguay if the deposits are large enough.

Northern Agricultural Zone—This zone is characterized by the extreme scattering and isolation of the farming areas. Few roads exist and none have all-weather surfaces. Nevertheless, there were over 10,000 ha planted to wheat in 1969; much of the harvest was marketed in Asuncion. Except for an unsurveyed deposit reported to be near Pedro Juan Caballero, lime deposits are isolated in the extreme northwest corner of the zone. No roads of any type connect the quarries with the agricultural areas. The quarries were developed solely to provide lime for the cement and construction industry in Asuncion—using the Rio Paraguay as the transportation artery.

Development of an agricultural limestone industry for northern Paraguay will not come easily yet one must be formed. Most of the soils are acid; over 50% of the soil samples from the Department of Amambay tested below pH 5.0 (table A-2). Farmers cannot afford to purchase lime from the Coronel Oviedo quarries and pay the high transportation charges that are necessary.

Currently the deposit at Vallemi, which is the only one known to have any dolomite, is operated by the GOP. Deposits at Itacua and Itapucumi are in private hands. These two quarries are under consideration as a source of calcitic limestone for the steel mills near Buenos Aires, Argentina. Stone from the Itapucumi quarry is most likely to meet chemical specifications. If a contract is made, the quarry, presumably, would be mechanized to produce lime aggregate 1.6-5.1 cm in diameter. This would be barged down the Paraguay and Parana Rivers to the mills. One or more barges might be used to transport agricultural lime to appropriate ports. Production of aggregate should result in about 75% of the material being satisfactorily sized and about 25% being undersized. [This proportion is based on the experience of quarries in the United States producing lime aggregate for highway construction (55).] The undersized material can be discarded or it can be ground into agricultual lime. Over 100,000 mt of agricultural lime could be produced annually via this process. Presumably, production costs for lime would be lower at this quarry than at any other quarry. Only a minimal charge would be made for the undersized raw material because it is a byproduct of aggregate production. No primary crusher would be necessary and power plant costs would be shared. Thus, plant investment costs also would be lower. Production costs should be no more than $4/mt but administrative and sales expenses would be at least equal to those for lime produced in the more accessible quarries. Mine costs for lime should be about $5/mt. Lime can be barged to Concepcion for less than $2.00/mt and to San Pedro for about $3.50/mt. From Concepcion to Pedro Juan Caballero, trucking charges are about $9.75/mt. Thus, farmers near this town would pay about $17.00/mt. This is less than three-fourths the cost of material trucked in from Coronel Oviedo. Farmers in the departments of Concepcion and San Pedro would pay about the same price for lime as farmers in most other parts of central and southern Paraguay.

If the Itapucumi quarry is not developed for aggregate production, then the GOP should produce agricultural lime at its quarry at Vallemi. The quarry already is mechanized and can crush 30 mt/hour. The dolomite in this quarry presently is used for construction aggregate but could be more profitably used for agricultural limestone production. Production costs would be similar to those derived in table 54, i.e., about $6.40/mt, although there might be some reduction because of the present mechanization. Transportation costs to Concepcion and San Pedro would be about $0.90/mt higher than for material produced at Itapucumi. Thus, delivered cost for lime produced at Vallemi would be about $2.30/mt higher than for Itapucumi lime but it would be dolomitic lime and worth slightly more than calcitic lime. Regardless of whether lime is produced at Vallemi or Itapucumi, the ports at Concepcion and San Pedro should be improved so that bulk lime could be unloaded from barges.

Nothing is known about the limestone deposit at Pedro Juan Caballero. Because a large part of the total cost of lime is for transportation, development of the deposit would be distinctly advantageous to farmers in the area. The area that could be serviced by this quarry depends only slightly upon whether the Itacua or the Vallemi quarry becomes the agricultural limestone producer. If it is Itapucumi, then the equi-cost point for the two market areas is 5 km west of the junction of Highway 3 and Highway 5. At the junction, Itapucumi lime would cost $11.88/mt and Pedro Juan Caballero lime would cost $11.48/mt. Farmers living south of this junction could purchase from either producer until lime received through San Pedro preempted the market. If the Vallemi deposit is the source that is developed, then the equi-cost point shifts 28 km west of the junction. No estimate has been made of the quantity of lime required by each of the three departments in the northern agricultural zone. If it eventually appears feasible to develop a limestone industry at Pedro Juan Caballero, as well as one on the Paraguay River, the size of each market should be estimated carefully before crushing and grinding equipment is ordered.

We recommend that private interests develop an agricultural limestone industry for northern Paraguay with quarries located at Itapucumi and Pedro Juan Caballero—if the deposit at this latter location proves feasible for development. The GOP should be prepared to produce lime at Vallemi if the Itapucumi venture does not materialize. The development of the northern agricultural zone for the production of crops is very dependent upon a reasonable cost for agricultural limestone. If quarries indigenous to the area cannot produce the lime, then GOP should consider subsidizing part of the transportation cost for lime produced at the Coronel Oviedo quarries.

Application

Very little comment will be made about the actual application of limestone to fields. For very small fields and farms without mechanization, it is assumed that most of the lime will be broadcast by hand. Farmers with very large and fully mechanized operations can afford to purchase applicators that can be used for both lime and fertilizers. Between the extremes are many farmers who have fields large enough to be handled mechanically but who cannot justify ownership of application equipment. Cooperative ownership of equipment is possible. Also, lime and fertilizer dealers or private entrepreneurs might invest in application equipment. Applicators then would either be leased to farmers or they could be used to custom apply lime and fertilizer.

Conservation of Resources

Paraguay is not noted for ample supplies of mineral resources but rather for the opposite. Possibly, lack of detailed mapping of the geology of the country has led to the assumption that mineral resources are lacking; possibly the country actually is deficient. Nevertheless, the mineral resources known to exist, such as limestone, should be managed wisely. The GOP could well establish guidelines for private investors to follow. Included would be conservative management of the limestone deposits.

In the United States a primary use for limestone is as aggregate for stabilizing highways. Undersize material is ground into agricultural limestone. This dual use greatly increases the quantity of stone that must be handled. More complete mechanization is possible and use of larger equipment reduces the unit cost of production. Paraguay also needs aggregate for highway construction but conservation of resources demands that the limestone be reserved for those uses where it alone will serve.

Limestone is needed both for agricultural purposes and for use in mortar. Here again it is possible to conserve mineral resources. Some of the limestone in the Coronel Oviedo deposits contains small amounts of phosphate. The phosphate is of no value in the mortar but of moderate value when applied to phosphorus-deficient soils. This phosphatic limestone, therefore, should be reserved for agricultural limestone.

At the Itacua quarry, overburden is being discarded as clayey material of no value. Actually, it is a rather high grade chalk quite suitable for liming purposes. Grinding costs would be minimal. Thus, instead of being discarded, the material should be stockpiled until it can be processed and sold for agricultural lime. Similarly, dolomite used for road aggregate at the GOP quarry at Vallemi should be reserved for a future need as agricultural lime.

FEASIBILITY OF DOMESTIC PRODUCTION OF FERTILIZER

The production of OSP involves one of the simplest fertilizer processes and it could have potential in developing countries if raw materials were available. However, Paraguay has no known resources of phosphate rock for commercial exploitation and no known deposits of sulfur for sulfuric acid production. It is technically feasible to operate an OSP plant with imported rock and sulfuric acid. An estimate was made to determine the economic feasibility of such an operation in Asuncion. The plant was sized to produce 14,000 mt P_2O_5/year because phosphate needs will be this high soon after 1980 (table 29).

Table 55 shows that domestic production of P_2O_5 is more than twice as expensive as importation. The domestic cost is based on importing both the phosphate rock and the sulfuric acid (table A-8). Should a deposit of rock phosphate be discovered in Paraguay and this rock charged into the plant at $5.50/mt (equal to the current cost of rock phosphate at the mine site), the cost of OSP could be reduced to $222.65/mt P_2O_5 (bulk). This still is $60/mt above the cost of imported phosphate. Thus, discovery of phosphate deposits of commercial grade within Paraguay would not necessarily lead to lower costs for fertilizer.

An alternative route to reducing the cost of OSP is to lower the cost of sulfur. The cost estimate in table 55 was based on sulfuric acid imported from Buenos Aires. Elemental sulfur purchased on the world market and converted into sulfuric acid at a plant in Asuncion is an alternative. As shown in table 56, the cost of phosphate still would be 50% more than imported P_2O_5. A 50% reduction in the world price of elemental sulfur lowers phosphate production costs less than $14/mt P_2O_5. It is not likely that world sulfur prices will fall this low for any sustained period of time. The other possibility is to discover sulfur in Paraguay and use it (at current world prices) to manufacture OSP. Again, as table 56 shows, cost of the P_2O_5 still is about $60/mt higher than imported P_2O_5. Unless both phosphate rock and elemental sulfur are discovered in commercial deposits in Paraguay, we do not recommend that phosphate fertilizer be manufactured within the

Table 55. Estimated Cost of Phosphate (from tables A-8 and A-10)

Type & source of phosphate	Analysis (N-P_2O_5-K_2O)	Cost[a] $/mt material	Cost[a] $/mt P_2O_5
Ordinary superphosphate produced in Paraguay	0-20-0	68.92	344.60
Triple superphosphate imported into Paraguay	0-46-0	74.86	162.74

[a]Bulk basis.

Table 56. Effect of Sulfur Cost on Phosphate Production Cost (from tables A-8 and A-9 and additional calculations)

Cost of sulfur: FOB mine	Cost of sulfur: Delivered	Production cost 93% acid	Phosphate production cost[a]: OSP	Phosphate production cost[a]: P_2O_5
		$/mt		
–	–	88.50[b]	68.92	344.60
38.00[c]	79.25	39.77	49.46	247.30
19.00[d]	58.35	32.91	46.71	233.55
38.00[e]	40.00	26.90	44.31	221.55

[a]Bulk basis.
[b]Sulfuric acid imported from Buenos Aires.
[c]Current world price.
[d]One-half of current world price.
[e]Estimated value of indigenous sulfur.

country. This statement is in accord with other TVA cost estimates that show that countries with a demand of less than 100 mt/day of P_2O_5—table 29 shows that Paraguay has a demand of 38.9 mt/day in 1980 should import finished fertilizer materials (37, 49, 40).

The domestic production of nitrogen fertilizer should not be attempted since raw materials such as natural gas, naphtha, coal, or byproduct hydrogen are not available in Paraguay. If some of these raw materials are found in the future and the fertilizer demand continues to increase as expected, further economic feasibility studies should be made at that time. Paraguay has no known reserves of potash. The nitrogen, phosphate, and potassium fertilizers for Paraguay must continue to be imported.

FERTILIZER IMPORTATION IN BAGS OR IN BULK BY VARIOUS ROUTES

Handling fertilizers in bags, rather than in bulk, adds measurably to their cost. Also, consistently importing by a single route sometimes results in higher costs through failure to take advantage of competition for business. Still another factor adding to the farmer's cost of fertilizer is warehousing virtually all fertilizers in Asuncion. True transportation costs in Paraguay are almost impossible to determine. It is fairly obvious, however, that transporting a ton of fertilizer from Asuncion to Coronel Oviedo or to any other locality one bag at a time is more costly than transporting the entire ton at one time. Although this example is extreme, it does illustrate the effect of centralized warehousing. Dispersed warehousing is advantageous to the farmer. All these factors were considered in a single analysis to determine the costs of imported fertilizers. The cost of using U.S. flagships, as contrasted to foreign flagships, was estimated at the same time.

The cost of five granular fertilizer materials—urea, AS, TSP, DAP, and KCl—delivered to various points in Paraguay was determined. The fertilizer was assumed to be from the Gulf Coast, U.S.A. FOB prices were chosen to reflect quotations expected to prevail in the future. At present, prices are somewhat lower due to a depressed market situation but they are not expected to remain at this low level. FOB prices per metric ton of bulk material were: urea, $47; TSP, $32; KCl, $27; DAP, $50; and AS, $9. A cost of $18/mt was added for bagged fertilizer. Shipping in both U.S. and foreign flagships was used to determine CIF costs for each of the routes into Paraguay. Delivered costs (CIF costs, port costs, transportation, and handling costs) were then determined to six selected market points.

Seven import routes were considered. Fertilizer was routed through the ocean ports of either Buenos Aires, Argentina, or Paranagua, Brazil. Four routes stemmed from Buenos Aires: via river to Asuncion and then truck to the six distribution points (route 1), via truck to Asuncion and on to the six points (route 2), via rail to Encarnacion with continuation to the rail depot nearest each of the six points plus truck from the rail depot when necessary (route 3), and via river to Encarnacion and then truck (route 4). Fertilizer entering the port at Paranagua was shipped by truck through Puerto Presidente Stroessner (route 5), by truck through Pedro Juan Caballero (route 6), or by rail to Pedro Juan Caballero and truck for the remaining distance (route 7).

The six distribution points are shown on figure 11. They are Coronel Oviedo, Paraguari, San Juan Bautista, San Pedro, Pedro Juan Caballero, and Encarnacion. Only Encarnacion is located on a river (the Parana). Both Encarnacion and Paraguari are located on the railroad.

Regardless of the route used or the fertilizer considered, bulk importation is less expensive than bagged. These savings originate from elimination of bags and bagging costs—usually about $18/mt of fertilizer—decreased transportation and handling costs, and lower customs fees and port charges. Savings generally range from about $40 to over $120/mt of plant nutrient (table 57). If these differences prevail throughout the next decade, the country could save over $18 million just by changing to bulk handling. Some, but not all, of these savings would be needed to install bulk handling facilities at the Asuncion and Encarnacion ports and at the various distribution centers. (A discussion of handling fertilizers in bulk follows later.) We recommend that Paraguay import fertilizers in

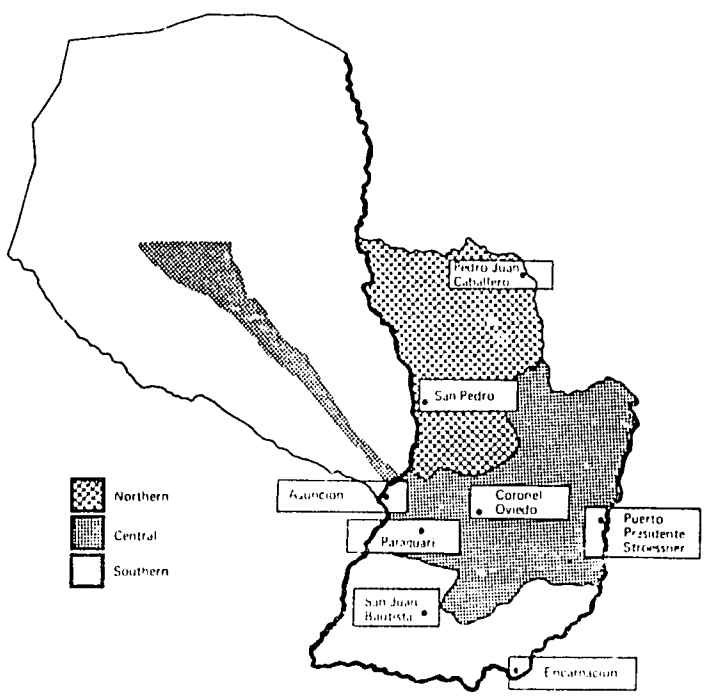


Figure 11. Agricultural zones and fertilizer distribution centers

Bagged fertilizers are more expensive than bulk.

bulk form just as soon as facilities can be made available to handle them.

U.S. laws require that 50% of the fertilizer imported under the auspices of AID, using either U.S. loan funds or grants, must travel in U.S. flagships when these are available. Shipping rates for these ships are higher than for ships flying a foreign flag. Many of the fees charged at the port of entry are based on CIF value. Markup, sales commission, and several other charges also are based on the value or cost of the fertilizer. Thus, the higher freight costs have a cascading effect, as shown in table 58. We recommend that as much fertilizer as possible be purchased with private funds; AID funds should be used when competitive bidding results in delivered costs that are lower, even though transportation in U. S. flagships is provided, or as a last resort for funds.

The route used to import fertilizers is an important factor to be considered in reducing the cost of the fertilizer. Each of the following tables (tables 59-63) considers the cost of importing a single material—urea, AS, TSP, KCl, and DAP—and transporting it to the six distribution centers throughout the country. The LCR appears to be rail transportation from Buenos Aires to Encarnacion (import route 3). Compared to the next higher-cost route, the advantage ranges up to as much as $30/mt of plant nutrient for urea and TSP and over twice this for nitrogen as AS. Unfortunately, the railroad is not in condition to handle fertilizer in bulk. If proper rolling stock and facilities were to be acquired, transportation charges undoubtedly would increase. The present competitive advantage would decrease and perhaps be lost entirely. Therefore, we do not recommend import route 3 for transport of bulk fertilizers.

It must be noted, however, that rail transportation of bagged fertilizers is feasible. Route 3 is the LCR for bagged fertilizers regardless of destination. Freight savings on a 1,000-mt shipment into Paraguay should be at least $6,000 compared to shipment by boat to Asuncion (tables A-10--A-16).

The next highest-cost route must be considered as the LCR for bulk fertilizers. In tables 59-63, both route 3 (LCR-bag) and LCR-bulk are printed in bold type. A quick glance shows that the type of bulk fertilizer does not affect the import route but the destination does. (This statement is valid only when all fertilizers depart the United States from ports in the same general area--East Coast, Gulf Coast, or West Coast.) For the six destinations, four different routes should be used. The only distribution center to which transport up the Parana and Paraguay Rivers (route 1 or the present system) qualifies as the LCR-bulk is Paraguari. Fertilizer destined for San Juan Bautista and Encarnacion also should be routed through Buenos Aires and up the Parana River but to Encarnacion, not Asuncion. The quantity of fertilizer that will be used in the southern agricultural zone warrants installation of bulk-handling facilities at the port in Encarnacion.

For the other three distribution centers, LCR-bulk depends upon the port at Paranagua rather than at Buenos Aires. Trucking the fertilizer from Paranagua is the cheapest transport mode to Coronel Oviedo and San Pedro. Rail is cheaper than truck when Pedro Juan Caballero is the destination.

We recommend that fertilizer be warehoused throughout the country rather than at Asuncion and that the fertilizer be imported via the LCR for each of the distribution centers.

Fertilizer does not have the same delivered cost at each of the distribution centers. The cost at San Pedro is about 20% greater than at Encarnacion. It is possible to equalize the delivered cost throughout the country and this is done in many countries for many commodities. With a disparity of only 20%, we do not believe that equalization of fertilizer prices is necessary.

Many technical problems will be encountered as the country moves into a program of handling fertilizers in bulk. Equipment to handle such fertilizers at the Asuncion and Encarnacion ports has been suggested but it was beyond the scope of this report to specify the exact items, size, and cost of such equipment. Similarly, some modifications in ships and barges probably would be desirable to better adapt them to transporting bulk fertilizers. Again, it

Table 57. Estimated Cost of Plant Nutrients, Bagged Versus Bulk (from tables A-10 to A-16)

Plant nutrient	Source material	Cost[a] Bagged	Bulk	Difference
			S/mt	
N	Urea	272.00	215.42	56.58
N	AS	384.97	262.16	122.81
P_2O_5	TSP	230.86	174.78	56.08
K_2O	KCl	167.80	124.82	42.98

[a]Mean for fertilizer imported by the LCR to six distribution centers, rail from Buenos Aires to Encarnacion excepted.

Table 58. Estimated Cost of Plant Nutrients, U.S. Flagship Versus Foreign Flag (from tables A-10 to A-16)

Plant nutrient	Source material	Cost[a] U.S. flag	Foreign flag	Difference
			S/mt	
N	Urea	260.47	215.42	45.05
N	AS	358.73	262.16	96.57
P_2O_5	TSP	218.87	167.48	51.39
K_2O	KCl	158.62	124.82	34.80

[a]Mean for bulk fertilizer imported by the LCR to six distribution centers, rail from Buenos Aires to Encarnacion excepted.

Table 59. Estimated Cost of Nitrogen Imported as Urea (45-0-0)[a]

Route & description	Distribution center: Pedro Juan Caballero	San Pedro	Coronel Oviedo	Paraguari	San Juan Bautista	Encarnacion
				S/mt		
Via Buenos Aires-Asuncion						
1 Boat	255.56	240.29	214.53	**211.18**	218.80	228.78
2 Truck	279.53	264.27	238.51	235.16	242.78	252.76
Via Buenos Aires-Encarnacion						
3 Rail	**219.38**	**204.73**	**182.51**	**178.76**	**183.11**	**173.24**
4 Boat	260.27	245.64	224.71	218.80	**211.18**	**201.20**
Via Paranagua-Puerto Presidente Stroessner						
5 Truck	246.93	**232.31**	**211.40**	217.09	224.71	234.69
Via Paranagua-Pedro Juan Caballero						
6 Truck	229.76	251.64	265.31	274.70	278.84	288.82
7 Rail	**225.22**	247.11	260.78	269.87	274.31	284.29

[a]Based on bulk material transported in foreign flagships (tables A-10 to A-16).

Table 60. Estimated Cost of Nitrogen Imported as Ammonium Sulfate (21-0-0)[a]

Route & description	Distribution center					
	Pedro Juan Caballero	San Pedro	Coronel Oviedo	Paraguari	San Juan Bautista	Encarnacion
				$/mt		
Via Buenos Aires-Asuncion						
1 Boat	348.19	315.48	260.29	**253.10**	269.43	290.81
2 Truck	399.62	366.90	311.71	304.52	320.86	342.24
Via Buenos Aires-Encarnacion						
3 Rail	**270.67**	**239.29**	**191.67**	**183.62**	**192.95**	**171.81**
4 Boat	358.29	326.95	282.10	269.43	**253.10**	**231.71**
Via Paranagua-Puerto Presidente Stroessner						
5 Truck	329.67	**298.33**	**253.52**	265.71	282.05	303.43
Via Paranagua-Pedro Juan Caballero						
6 Truck	292.86	339.76	369.05	388.52	398.05	419.43
7 Rail	**283.19**	330.10	359.38	378.86	388.38	409.76

[a]See footnote "a" table 59.

Table 61. Estimated Cost of Phosphate Imported as Triple Superphosphate (0-46-0)[a]

Route & description	Distribution center					
	Pedro Juan Caballero	San Pedro	Coronel Oviedo	Paraguari	San Juan Bautista	Encarnacion
				$/mt		
Via Buenos Aires-Asuncion						
1 Boat	214.04	199.11	173.91	**170.63**	178.09	187.85
2 Truck	237.52	222.59	197.39	194.11	201.57	211.33
Via Buenos Aires-Encarnacion						
3 Rail	**178.67**	**164.35**	**142.61**	**138.93**	**143.20**	**133.54**
4 Boat	218.65	204.35	183.87	178.09	**170.63**	**160.87**
Via Paranagua-Puerto Presidente Stroessner						
5 Truck	205.61	**191.30**	**170.85**	176.41	183.87	193.63
Via Paranagua-Pedro Juan Caballero						
6 Truck	188.83	210.24	223.61	232.50	236.85	246.61
7 Rail	**184.39**	205.80	219.17	228.07	232.41	242.17

[a]See footnote "a" table 59.

was not possible in this study to investigate these kinds of details.

We recommend that a detailed study be made of the facilities and equipment needed to handle fertilizers in bulk from the ocean ports to the warehouses in Paraguay.

DISTRIBUTION AND MARKETING OF IMPORTED FERTILIZERS

It has been shown that fertilizers imported in bulk are less expensive than fertilizers imported in bags. Similarly, costs are decreased when fertilizers are imported via the LCR to distribution centers dispersed throughout the country. One further analysis possibly should have been made; this would have compared the cost of mixed fertilizers with straight materials. The price of a mixed fertilizer is based on the amount of each plant nutrient present—plus many additional factors—but is not quoted in this way. Only the final summation is quoted. This makes it impossible to compare the price of two different grades of mixed fertilizers unless the grades have the same $N:P_2O_5:K_2O$ ratio. For this reason, all comparisons above have been based on straight materials urea, AS, TSP, and KCl. Generally, it can be assumed that mixed fertilizers are more expensive than straight materials because of the additional operations required to bring all the necessary ingredients together in one location and mix them uniformly to a preselected grade.

In many situations mixed fertilizers are worth their additional cost. There are some slight agronomic advantages when nitrogen and phosphorus are present in the same

Table 62. Estimated Cost of Potash Imported as Muriate of Potash (0-0-60)[a]

Route & description	Distribution center					
	Pedro Juan Caballero	San Pedro	Coronel Oviedo	Paraguari	San Juan Bautista	Encarnacion
				S/mt		
Via Buenos Aires-Asuncion						
1 Boat	154.92	143.47	124.15	**121.63**	127.35	134.83
2 Truck	172.92	161.47	142.15	139.63	145.35	152.83
Via Buenos Aires-Encarnacion						
3 Rail	**127.78**	**116.80**	**100.13**	**97.32**	**100.58**	**93.18**
4 Boat	158.45	147.48	121.78	127.35	**121.63**	**114.15**
Via Paranagua-Puerto Presidente Stroessner						
5 Truck	148.47	**137.50**	**121.82**	126.08	131.80	139.28
Via Paranagua-Pedro Juan Caballero						
6 Truck	135.58	152.00	162.25	169.07	172.40	179.88
7 Rail	**132.18**	148.60	158.85	165.67	169.00	176.48

[a]See footnote "a" table 59.

Table 63. Estimated Cost of Nitrogen and Phosphate Imported as Diammonium Phosphate (18-46-0)[a]

Route & description	Distribution center					
	Pedro Juan Caballero	San Pedro	Coronel Oviedo	Paraguari	San Juan Bautista	Encarnacion
				S/mt		
Via Buenos Aires-Asuncion						
1 Boat	118.31	111.44	99.85	**98.34**	101.77	106.26
2 Truck	129.10	122.23	110.64	109.13	112.56	117.05
Via Buenos Aires-Encarnacion						
3 Rail	**102.03**	**95.44**	**85.44**	**83.75**	**85.71**	**81.27**
4 Boat	120.43	113.85	104.43	101.77	**98.34**	**93.85**
Via Paranagua-Puerto Presidente Stroessner						
5 Truck	114.43	**107.85**	**98.44**	101.00	104.43	108.92
Via Paranagua-Pedro Juan Caballero						
6 Truck	106.70	116.55	122.70	126.79	128.79	133.28
7 Rail	**104.67**	114.52	120.67	124.76	126.76	131.25

[a]See footnote "a" table 59.

granule. When only a very small amount of fertilizer is needed, it is simpler and more economical to purchase one bag of mixed fertilizer rather than one bag each of the three straight materials required to prepare a mixture. Similarly, educational programs for farmers are easier to conduct when all that is necessary is to recommend three bags of fertilizer (mixed) per hectare rather than 1-1/2 bags of urea, 2/3 bag of TSP, and 5/6 bag of KCl.

A fertilizer program based on mixtures, however, requires a large number of different ratios or grades in order for each field to be fertilized according to its fertility characteristics and the crop to be grown. Thus, in addition to the higher initial cost of mixed fertilizers, there must be added the higher cost of maintaining an inventory of many different mixtures and of ordering smaller quantities of the several mixtures.

One way to solve the dilemma of the high cost of bagged, mixed fertilizers versus the difficulty of applying the proper amount of each of several straight materials is to purchase straight materials in bulk and blend them in as many different ratios as are needed. The blended material can be sold to the customer in bulk if he is able to handle it in that form or it can be bagged for those who so prefer. Fertilizer bagged in the country of use rather than the country of origin is cheaper because of reduced transportation costs and lower labor costs.

Paraguay already has reached the point that bulk blending is feasible. This was the conclusion of the BNF-Arthur D. Little study in 1967 (13) and of Adela Investment Company in 1970 (44). An immediate and complete change to bulk materials is not possible but the

change should be expedited and made as soon as possible. The ports at Encarnacion and Asuncion need to install facilities for handling bulk fertilizers before it is feasible to import bulk materials through Buenos Aires. For materials that can be received through Paranagua, no delay is necessary. Nitroquimica Paraguay is planning to obtain bulk material from Paranagua for its blending plant in Asuncion.

We recommend blending in Paraguay of the bulk fertilizer imported into the country.

Number, Location, and Size of Bulk-Blending Plants

Blending plants in the United States normally service only farmers within a radius of 15-20 miles (24-32 km) of the plant. In Paraguay, settlement of land still is sparse and tends to occur in long, narrow bands along roads. The Plan Triangulo investigation showed that almost all land cleared for cultivation is located within 10 km of an existing road (12). Thus, bulk-blending plants in Paraguay must serve rectangular areas. The average length of haul in a rectangular service area is greater than in a circular area of the same hectarage. This average length of haul increases exponentially as the length of the rectangle increases in proportion to its width. Therefore, rectangles should be kept as short and as wide as possible but not to the extent that economy of distribution reduces the economy of production that is attained by keeping plant size large. Most solutions that consider economy of distribution simultaneously with economy of size show that several medium-sized plants are more economical than a single very large plant.

Another factor that promotes more, rather than fewer, blending plants is the comparative cost of transporting raw materials and finished products. Raw materials for blending will be handled in bulk, using trucks up to 30 mt in capacity for highway transit. The blended product, both in bulk and in bags, will be handled in 10-mt or smaller trucks. Although present rate schedules do not use load size as a rate-determining factor, interviews with trucking firms showed they were willing to negotiate lower fees for large volume. Thus, costs can be minimized by hauling raw material as far as possible and blended product as little as possible.

The number, size, and location of bulk-blending plants needed to minimize the cost of fertilizer delivered to farmers' fields could be determined very precisely if factors, such as farm location, rate of fertilizer use, cost of fertilizer, transportation, and markup or other charges, were known. Lacking these data, an alternative method of determining the size and location of plants was used. That is, fertilizer needs for various areas of the country for 1975 and 1980 were estimated. An assumption was made that fertilizer intended for use on wheat would be applied in bulk and that intended for all other crops would be bagged. A 1-mt rotary mixer can blend 20 mt/hour or 200 mt in a 10-hour day. Assuming further that 60 days are available each fall for applying fertilizer to wheat, a plant can produce 12,000 mt of bulk-blended fertilizer for bulk application. (During the remainder of the year, the plant could produce up to 54,000 mt of bagged blends.) Larger mixers are available and could be used but location of the plant and the market must be considered before deciding on plant size.

By 1975 estimated fertilizer requirements for wheat are 25,151 mt (table 47). This estimate is based on using ammonium sulfate, diammonium phosphate, and muriate of potash as the nutrient sources. As shown in table 43, however, wheat hectarage is about equally divided among the three agricultural zones in eastern Paraguay. Fertilizer nutrient requirements for wheat-soybeans in each of these areas in 1975 are 8,585, 9,344, and 7,222 mt (table 47). These requirements could be satisfied by a 1-mt mixer in each zone; area fertilizer requirements for other crops do not exceed the annual capacity of a plant of this size.

Before specifying the location of plants for 1975, projected fertilizer requirements in 1980 for wheat and other crops were also considered (table 47). As expected, fertilizer blends needed for wheat-soybeans exceeded the production limits imposed by a 1-mt mixer. By 1980, each of the three zones will require either two bulk-blending plants or a larger mixer in the original plant. Again, analysis of length of haul and size of the market shows that two medium-sized plants per zone would be more economical than one very large plant. Thus, the location of the first three plants must be selected to allow for an additional plant in each area by 1980.

Fertilizer demand is greatest in the central zone and a plant for this area should be constructed as soon as possible. We suggest 1972 as the target date and suggest Coronel Oviedo as the location. A plant located here is at the very center of eastern Paraguay and can ship product north to San Pedro, south to Villarrica, east to Puerto Presidente Stroessner, and west to San Lorenzo. As shown in table 64, the production capacity for fertilizer blends for wheat-soybeans will be reached in about 1975. A second plant will be needed in the area for the 1976 season. We suggest that this plant be located at Paraguari. By 1980 even this plant will be operating at capacity and a third plant should be considered for the area. San Lorenzo would be a possible location but a re-evaluation of fertilizer demand in the area at that time could show that the third plant should be located at Puerto Presidente Stroessner.

For the southern area we suggest plants at San Juan Bautista and Encarnacion. The plant at San Juan Bautista should be constructed first. We suggest that this plant be placed in operation by 1973. Nitroquimica Paraguay presently is establishing a blending plant in Asuncion and

Table 64. Location and Estimated Production Volume of Blending Plants

Plant location	Date needed	Crop	Volume 1975	Volume 1980
			mt	
Northern zone				
Pedro Juan Caballero	1974	Wheat/soybean	8,585	8,238
		Other	2,403	2,543
		Total	10,988	10,781
San Pedro	1976	Wheat/soybean	–	8,752
		Other	–	3,142
		Total	–	11,894
Central zone				
Coronel Oviedo	1972	Wheat/soybean	9,344	7,832
		Other	12,080	15,426
		Total	21,424	23,258
Paraguari	1976	Wheat/soybean	–	10,904
		Other	–	15,085
		Total	–	25,989
Southern zone				
San Juan Bautista	1973	Wheat/soybean	7,222	7,923
		Other	6,462	5,907
		Total	13,684	13,830
Encarnacion	1977	Wheat/soybean	–	6,744
		Other	–	10,167
		Total	–	16,911

expects to be in operation in 1971. We suggest that trial shipments of blended fertilizers be made to the Misiones area in 1971 and 1972 to establish farmer acceptance of bulk application. (Whether the company moves its plant to this or some other area or establishes additional plants is not germane to this report.) According to our estimates, demands should exceed production limitations by 1977 and a new plant will be needed. We suggest that this second plant be located at Encarnacion in order to reduce the hauling distance for farmers to the south and east of San Juan Bautista.

In the northern zone, only dirt roads exist and settlements are widely scattered. Nevertheless, fertilizer is hauled from Asuncion to the various colonies and even to Pedro Juan Caballero for use on wheat and coffee. A bulk-blending plant at Coronel Oviedo is in a better position than warehouses in Asuncion to supply this northern area. However, the Coronel Oviedo plant cannot long supply both areas. Thus we suggest that a plant be constructed at Pedro Juan Caballero in 1974 and another at San Pedro in 1976.

We recommend that six bulk-blending plants be constructed in eastern Paraguay during the next decade. The size of the plants will be large by U.S. standards but size is controlled by the amount of fertilizer that must be blended for farmers in the area serviced by the plant. The location of the plants, except for the first two or three, can only be predicted at this time. As the need for another plant develops, its best location will be fairly obvious.

Cost and Operation of Bulk-Blending Plants

A bulk-blending fertilizer process consists of physically mixing dry solid materials to produce products of different N, P_2O_5, and K_2O contents. Formulations are readily changed to meet the demand. Bulk blending works best with materials that are well granulated, closely sized, and sufficiently dry and strong so that they do not cake or deteriorate during storage and handling. The particle size of the materials used in blending should be 6- to 16-mesh, with only minor fractions above or below these specifications. Specifications of some materials used in bulk blending are given in table 65. No chemical reaction between the materials should occur during or after mixing.

When a bulk-blending plant for a particular area is being considered, one of the most important factors is the availability and cost of raw materials. As seen in table 57, shipment of the lower grade ammonium sulfate (21% N) over the long distance to Paraguay puts this material in a poor competitive position with urea (45% N) on a cost per unit nitrogen basis. However, in a developing country, such

Table 65. Typical Specifications for Some Materials Used in Bulk Blending (2)

Material	Apparent specific gravity	Grade (N-P_2O_5-K_2O)	Tyler screen range +6	−6 +8	−8 +10	−10 +16	−16	Particle shape
					Wt %			
Urea prills, unconditioned	1.32	46-0-0	0	1	17	78	4	Extremely well rounded
Urea prills, conditioned	1.32	45-0-0	0	0	1	94	5	Extremely well rounded
Ammonium sulfate, flakes	1.64	21-0-0	0	6	46	41	7	Irregular
Ammonium sulfate, crystals	1.75	21-0-0	0	2	38	51	9	Rounded
Diammonium phosphate, granular	1.63	18-46-0	0	5	83	12	0	Well rounded
Triple superphosphate, granular	2.12	0-46-0	<1	29	56	14	<1	Well rounded
Potassium chloride								
Flotation product, granular	1.97	0-0-60	2	36	52	10	0	Blocky
Flotation product, coarse	–	0-0-60	0	0	19	51	30	Blocky
Solution rounded crystals	1.93	0-0-62	0	5	29	58	8	Well rounded
Compacted flakes	1.96	0-0-60	0	14	65	20	1	Irregular
Filler								
Crushed limestone	2.53	0-0-0	0	9	60	26	5	Irregular

as Paraguay, fewer problems are expected in handling this material compared with urea. First operation in the country should begin with materials that are easiest to handle. Therefore, ammonium sulfate probably should be used until experience in handling and storing urea in bulk can be obtained. Small test shipments of bulk urea could be made to gain experience and confidence in handling and storing this material. Tests are currently under way in various parts of the world to define problems that may develop with bulk shipments of urea. No serious difficulties with bulk shipment of the other materials used in bulk blending are expected.

A bulk-blending plant consists basically of a raw material handling and storage system, metering or measuring devices for raw materials, a mixer, and a product handling system. Most plants have facilities for bagging a portion of the product. Some companies offer package bulk blending plants in the United States of various designs; however, many plants have been designed for specific locations and built for special applications. Consequently, the plants in use vary considerably in design and operation (1).

Storage buildings for raw materials are of two general types, ground storage and vertical storage. Ground storage is used most frequently and materials are stored in compartmented bins that are accessible by several methods. Conveyors of a belt, screw, or bucket type can be used to fill the bins; the method chosen will depend upon the transport system for getting raw materials to the plant. Materials in modern plants are generally delivered to the weighing system by a scoop truck or front-end loader. In vertical storage, raw materials are stored in above-ground compartmented bins that are filled by elevators. Materials then flow by gravity to the weighing and mixing system. Weighing or metering of raw materials can be accomplished in several ways. A weigh belt, weigh hopper, or any other convenient weighing device can be used. The front-end loader can be weighed on platform scales. If calibrated accurately, a volumetric metering system would be satisfactory.

One of the most popular mixers used in bulk blending is the rotary type. The mixer is similar to that used on a concrete-mixing truck. The capacity ranges from 1 to 5 mt. Generally, a 1-mt mixer is capable of producing 20 mt/hour of blended material. The output, of course, depends on the time requirement for metering, mixing, and discharging. In efficient plants, this type cycle is about three minutes; the mixing time is usually about one minute. A modified screw conveyor can also be used as a mixer; slots are cut in the flights to increase retention time and improve mixing. Another mixer in use has an internal ribbon-type agitator for tumbling of the material and has a capacity of 1-4 mt. One of the simplest and most economical mixing types is based on gravity flow to accomplish the mixing. Material is conveyed to the top of the vertical mixer (about 10 m high) after weighing. The material is released and falls downward through a torturous path and mixing is accomplished. These mixers can be constructed of wood for about $1,000 in the United States. TVA designed a mixer of this type and specifications may be obtained by writing to TVA. This type of mixer is readily adaptable for use in developing countries.

Blended product from the mixer flows to a receiver such as a truck or to the bagging system. No unbagged product

storage is recommended. To obtain maximum efficiency and economy from a bulk-blend operation, raw materials should be purchased in bulk and all product marketed in bulk. However, in some areas it is not possible to market all the product in bulk. Therefore, some bag storage is recommended. The required storage capacity for raw materials depends upon such factors as availability and access to deliveries, number and types of materials needed, and, of course, plant output. In some areas where freight is a large portion of the cost, larger storage is recommended. If storage is available, economies in volume purchases can be realized. However, storage requires a relatively high capital investment and is a significant portion of the cost of a bulk-blending facility.

An estimate of investment costs for two types and sizes of bulk-blending plants is given in table 66. Both plants are capable of producing 12,000 mt of blended fertilizer in 60 days for use on wheat-soybeans. This determines the minimum size of the plants. Rated capacity of both plants is 66,000 mt/year which is greatly in excess of needs. Annual production will be 20,000-26,000 mt (table 64). The plant containing the rotary blender, located at Coronel Oviedo in this example, must produce 16,000 mt of bagged fertilizer; therefore, it is equipped with an automatic bagging machine and forklift. The tower (gravity flow) blender is located at Pedro Juan Caballero in this example. Less than 3,000 mt of bagged fertilizer will be needed and so a semiautomatic bagging machine is used.

Table 66. Estimated Plant Investment for Two Types and Sizes of Blending Plants

Equipment	Rotary blender[a] (24,000 mt/yr)	Tower blender[b] (12,000 mt/yr)
	$	
Portable conveyor	1,000	1,000
Pay loader	6,000	6,000
Platform scales	1,500	1,500
Scalping screen	100	100
Elevators (2)	6,000	6,000
Holding hopper	200[c]	200[c]
Blender	2,000	500
Product hopper	200[c]	200[c]
Bagging machine[d]	4,000	1,500
Forklift	6,000	–
Subtotal	27,000	17,000
Delivery & installation, 40% of U.S. cost	10,800	6,800
Equipment cost	37,800	23,800
Bulk storage, $10/mt	80,000	80,000
Bag storage, $10/mt	80,000	15,000
Total plant investment	197,800	118,800

[a]Size and storage based on 1980 projections for Coronel Oviedo.
[b]Size and storage based on 1980 projections for Pedro Juan Caballero.
[c]Local supplies.
[d]Fully automatic for rotary blender plant and semiautomatic for tower blender plant.

In comparison to blending plants in the United States, investment costs are high. This is due almost solely to the storage capacity included in the design. The plants must produce 7,800 and 8,200 mt of blends in just 60 days for wheat-soybeans. The odds that imports can be scheduled to arrive exactly when needed are not sufficient to rely upon manufacturers' and in-transit storage. Blending plants in Paraguay should have adequate storage to ensure that customers always can obtain fertilizers when needed. Bagged storage is not as critical as raw material storage and so the design includes storage capacity for only one-half of production. It is assumed that the longer sales season for bagged fertilizer will result in half the material being sold for on-the-farm storage. In an emergency, storage for bagged fertilizer can be leased in a nearby building or even in some other town. This is not possible for raw materials.

The cost of blending fertilizers in the two plants is given in table 67. The analysis is subdivided to show the cost of blending for fertilizer sold in bulk and of blending and bagging for that sold in bags. These are the costs that must be added to the cost of the raw materials (imported fertilizers) when filling a customer's order. The plant at Coronel Oviedo operates at a lower cost per ton of fertilizer blended than the one at Pedro Juan Caballero. This is because of the higher volume and not because of the type of mixer used. Lower throughput at either plant, as will happen during the first years of operation, will increase the cost of processing each ton but the increase will not be so very great. Lower throughput also requires less working capital and less labor costs. Plant managers should estimate their throughput and production costs each year in order to make adequate charges for the fertilizer sold. Administrative and marketing costs are not included in the above production costs.

We recommend that a careful study be made of the scheduling of fertilizer shipments because they affect the amount of storage capacity and working capital needed by a bulk-blending plant. Storage capacity is one of the most costly parts of a blending plant's physical facilities. Working capital requirements are also controlled by the quantity and value of material that must be stored. If imports can be scheduled more frequently with no penalty for smaller tonnages and complete assurance that delivery will be by the date needed, bulk storage requirements can be reduced. The cost of operating the bulk blending plant would also be reduced and farmers would not have to pay as much for fertilizer.

Marketing of Blended Fertilizers

The present system consists of both a private and a public sector engaged in the importation, distribution, and marketing of fertilizers. Within the private sector there have been numerous entrants but few companies remain active.

Table 67. Estimated Capital, Variable, and Fixed Costs for Bulk and Bagged Blends

	Rotary blender		Tower blender	
	Bulk	Bagged	Bulk	Bagged
	mt			
Estimated production	8,000	16,000	9,000	3,000
Capital investment	$			
Plant[a]	197,800		118,800	
Working capital[b]	360,000		393,000	
Total	557,800		511,800	
Variable Costs[c]	$/mt			
Power[d]	0.10	0.20	0.10	0.15
Product loss	.20	.40	.50	1.00
Total	.30	.60	.60	1.15
Fixed costs				
Operating labor[e]	.31	.31	.57	.40
Maintenance, 5% of plant investment	.41	.41	.50	.50
Analysis, 10% of operating labor	.03	.03	.06	.04
Supplies, 20% of maintenance	.08	.08	.10	.10
Bags	–	4.20	–	4.20
Overhead, 100% of operating labor	.31	.31	.57	.40
Insurance, 2% of plant investment	.16	.16	.20	.20
Depreciation (15 yr)	.55	.55	.66	.66
Return on plant investment, 10%	.82	.82	.99	.99
Interest on working capital, 8%[f]	.60	.60	1.31	1.31
Interest on plant investment, 8%[f]	.33	.33	.40	.40
Total	3.60	7.80	5.36	9.20
Total cost of production	3.90	8.40	5.96	10.35

[a]From table 66.
[b]Equivalent to one-half the annual cost of raw material.
[c]Excludes cost of the raw material.
[d]Power costs have been estimated but generator units have not been included as a part of the plant equipment. It is assumed that power will be available at nearly all proposed plant locations before the plants are built.
[e]

Labor	Rotary blender Bulk	Rotary blender Bagged	Tower blender Bulk	Tower blender Bagged
	$			
1 supervisor, $250/month	1,000	2,000	2,500	500
3 laborers, $60/month	360	720	360	180
Fringe benefits, 80%	1,088	2,176	2,288	524
Total	2,488	4,896	5,148	1,204
$/mt	0.31	0.31	0.57	0.40

[f]Due to amortization, average annual rate is 4%.

BNF is too formidable a competitor. As an agent of the government, the bank is able to reserve for itself those customers who cooperate in government programs. Thus, it has a minimum of sales and promotion expenses. Neither does the bank need to make a profit, as does a private company; margins need only cover out-of-pocket costs. In defense of BNF, it should be pointed out that private industry appears to have been loath to commit itself to as rapid an expansion of fertilizer use as government programs required. BNF has capably fulfilled this additional demand.

We suggest, however, that sale of fertilizers in Paraguay be handled in the private sect . BNF should dispose of its stocks of fertilizer presently in storage and on order as expeditiously as possible say in one to two years. In the meantime, private industry should be preparing to absorb the volume of business that will be released by the bank. This suggestion is not intended to mean that BNF will be completely divorced from fertilizers and its role in agricultural development. BNF's involvement in the fertilizer program is discussed in a later section on agricultural credit.

We do not suggest any particular role for cooperatives in fertilizer distribution and marketing. The impetus for a successful fertilizer program must originate from a combination of government interest and private initiative, as exhibited by the present National Wheat Program. A large, dramatic program is required to increase the volume of fertilizer use to the point that more modern handling methods can be adopted. Only after this effort has demonstrated success and caused the price of fertilizers to decline can fertilizer use be extended generally and particularly to the smaller farmers. At this latter time, then, cooperative associations of the small landholders can be formed to consolidate purchases, delivery, and credit for fertilizers.

Several alternatives are possible in developing a marketing system for blended fertilizers. There are many advantages for a single purchasing authority—and an equal number of disadvantages. Such an agency, possibly a consortium of the private companies, would be able to purchase fertilizer in large quantities on the world market at the most reasonable price. It is possible, also, for this agency to operate the bulk-blending plants. The private companies would constitute the sales organization. They would purchase both bagged and bulk blends from the nearest bulk-blending plant and resell to their customers. This type of organization, however, destroys any affiliation that the present companies have with large, international fertilizer concerns.

A review of table 64 shows that the volume of fertilizer to be handled at each bulk-blending plant is larger than any company presently is handling in Paraguay. The present companies, then, could expand their business, if they desired, by handling fertilizer in bulk. (Even ordering mixed fertilizers in bulk and simply bagging them in Paraguay

would reduce the price of the fertilizer to such an extent that imported bagged fertilizer would be priced out of the market.) Each company could import fertilizer from its parent company or any other source that it desired. Bagged fertilizers containing micronutrients or other special ingredients could also be purchased if desired but could be blended nearly as easily in the bulk-blending plant. This type of market leaves the initiative with the private companies. If one or more does not follow through and establish bulk-blending plants, GOP would be forced to remain the major procurer and disburser of fertilizer. BNF, or a new agency organized to handle fertilizers, would then become the purchasing agency, operator of the bulk-blending plants, and probably the sole sales agency.

Assuming that private industry does move into bulk fertilizers, each company should determine its market objectives and analyze the market potential within its prospective sales area(s). Although the headquarters office might well remain in Asuncion, regional and local sales offices should be established in accord with the marketing plan. The bulk blending plant should be located so as to service the sales area as economically as possible yet provide room for one or more additional plants as fertilizer use increases. Possibly warehouses for bagged blends should be located with the local sales offices. If warehousing for a substantial quantity of bagged material is established at a location other than the blending plant, the amount of storage at the blending plant should be reduced. The cost of storage, regardless of location, already has been included in the cost of production. Cost of transportation to a secondary warehouse, however, must be added to the cost of the fertilizer. Markup on bulk and bagged blends to cover administrative and sales expenses (probably about 15%) would be determined by each company. Competition would prevent too high a markup.

Each company operating a blending plant can expect to have two fertilizer seasons. The discussion above intimated that blended fertilizers used on wheat will be applied in bulk and those used on other crops will be bagged. These generalizations are too broad. The production, marketing, and use of blended fertilizers for fall application to wheat and spring application to other crops is covered in more detail in the following section.

Fall-Applied Blends Wheat and a few vegetables are about the only crops planted in the fall although coffee, citrus, and other perennial crops frequently are fertilized in the fall. In order to estimate plant size and location, bulk application of wheat fertilizers is assumed to be the most probable limiting factor. We suggest the practice but caution that it is a new practice—for Paraguay—and must be tested and accepted by farmers. Farmers will continue to purchase and use bagged fertilizers until they are convinced that bulk application is a cheaper, faster, and more satisfactory method of application than drilled fertilizer. Thus, bulk application cannot be planned for 100% acceptance by any particular year.

The suggested distribution/marketing system for wheat farmers is based on farmer-owned equipment. Fertilizer would be purchased on the basis of soil test and advice from the company agronomist. The farmer would send his truck(s) to the plant on the day(s) that he wanted to apply the fertilizer. (Blended fertilizers frequently are hygroscopic and cannot stand long exposure to high humidity without caking. The usual practice is to apply them the same day they are blended.) At the farm or field, the fertilizer would be transferred to a tractor-pulled bulk distributor that holds 3-5 mt. These spreaders apply fertilizer to about 5 ha/hour or 50 ha/day. For a 60-day application season, one spreader theoretically could handle 3,000 ha. The same spreader can be used to apply agricultural limestone. Cost of a spreader with flotation tires is approximately $4,000 in the United States.

A farmer's fertilizer cost, then, is the price at the plant plus trucking and application costs. By moving plants closer and closer to farmers, trucking costs are reduced. By handling and applying in bulk, the cost of application also is reduced. Bulk spreaders usually cause fewer delays in application than drill-type applicators. Since the fertilizer is applied before the wheat is planted, fewer delays are experienced during the actual planting operations. For farmers with large hectarages, speed or timeliness of planting is an important factor.

Spring-Applied Blends—Most of the fertilizer produced for spring application probably will be bagged. This fertilizer can be blended and bagged at any time of the year. It can be stored at the blending plant or trucked to warehouses anywhere in the total area serviced by the blending plant. Bags containing blended fertilizers should have air-tight seals to prevent moisture from entering and causing caking. Blended fertilizers are used in the same way as the chemically mixed fertilizers currently imported into Paraguay.

In some areas, field sizes of spring-planted crops are large enough that bulk application is feasible. In a few instances, farm sizes will be large enough for farmers to own their own bulk spreaders, just as was recommended for wheat farmers. In most other cases, farms are too small to warrant ownership of a bulk spreader. In these areas, the local office of the fertilizer company should purchase one or more spreaders. These can range in size from 1 mt up to 4 or 5 mt. The company either rents an applicator to a farmer or custom applies fertilizer in accord with a farmer's purchase and specifications. Usual rates in the United States for custom application are $2.50/ha (30).

We recommend that private industry operate the bulk-blending plants and market the fertilizer in Paraguay.

ECONOMIC RETURNS FROM LIME AND FERTILIZER

The value of the increase in crop yield must exceed the cost of lime and fertilizer if these are to be used by farmers, that is,

$$\frac{\text{Value of increase in yield of crop (₲/ha)}}{\text{Cost of lime and fertilizer (₲/ha)}} \geqslant 1.00$$

When the benefit/cost ratio exceeds 1.00 only slightly, farmers usually will not use the lime or fertilizer. The risk is still too high. A crop failure one year out of five would require a ratio of 1.25 just to break even. There are no precise rules for determining the magnitude of the benefit/cost ratio needed to motivate farmers to adopt a new practice. Generally, it is thought the ratio should be at least 3.00 in developed countries where farmers are more accustomed to trying something new. In developing countries, where farming practices may not have changed for a century or more, the benefit/cost ratio must be much higher–possibly 6.00-10.00–and must be easily observed before farmers will try something new.

Two variables enter into benefit/cost ratios: commodity value and input (lime and/or fertilizer) cost. Both can be controlled by government actions. Lime and fertilizer can be furnished at a subsidized cost or a favorable (or unfavorable) market price can be set for the commodity. In many situations, free market conditions prevail and lime and fertilizer use must stand on their own economic merits.

Prices of farm commodities in Paraguay fluctuate to a certain extent and are usually at the lowest point during the main harvest season. Annual means for most commodities do not vary greatly. Consequently, mean prices for the period 1962-1969 were used in determining benefit/cost ratios (table 68). There is no assurance, of course, that these prices will prevail during the next decade; they seem, however, to be the best available estimate of prices.

One of the paradoxes in Paraguay is the low volume of fertilizer use because of the high price and the high price because of the low volume. Breaking this paradox is a major goal of this study. By concentrating on crops that respond economically at present price relationships, volume of use can be increased and cost can be decreased. With each decrease in cost, use can be extended to more and more crops: those that have lesser monetary value as well as those that give a lesser physical response.

To provide prices for calculating benefit/cost ratios, we have determined an approximate "current" cost of fertilizer, a reduced cost caused only by a change in import route, and a minimum cost based on bulk blending. That is, for 1971 we estimated the cost of plant nutrients purchased in 50-kg bags and shipped from the U.S. Gulf Coast in U.S. flagships to Buenos Aires, then via FME to Asuncion and

Table 68. Average Price of Farm Commodities (29, 51)

Commodity	1962	1963	1964	1965	1966	1967	1968	1969	Mean
					₲/kg				
Alfalfa	4.0	4.4	4.9	4.6	4.8	5.0	5.0	4.0	4.2
Bananas	–	–	–	–	–	–	–	–	1.9
Beans	11.2	12.9	13.7	11.0	11.8	10.8	10.0	12.0	11.7
Coffee	–	–	–	–	–	–	–	–	47.0
Corn	4.5	6.0	5.4	4.5	6.4	4.7	4.0	5.0	5.1
Cotton	16.4	16.9	17.0	16.5	14.4	14.2	16.0	14.0	15.7
Lemons	–	–	–	–	–	–	–	–	13.0
Mandioca	2.6	2.8	2.6	2.5	2.8	2.9	2.0	2.7	2.6
Onions	16.2	15.1	10.8	12.5	3.5	13.5	11.0	12.0	13.1
Oranges	–	–	–	–	–	–	–	–	2.8
Peanuts	11.8	13.4	14.4	14.0	13.8	12.1	12.0	12.0	12.9
Peas	11.1	13.2	13.2	14.0	13.7	13.8	13.3	12.0	13.0
Petit-grain oil	556	417	414	405	410	411	447	360	427.5
Pineapple	–	–	–	–	–	–	–	–	13.2
Potatoes	14.3	18.3	14.8	11 5	13.1	15.2	11.0	12.0	13.8
Rice	9.3	12.6	12.2	11.0	11.2	9.3	10.0	9.0	10.6
Soybeans	9.6	9.6	9.7	8.0	10.4	8.2	8.0	7.5	8.9
Sugarcane	0.6	0.6	0.7	0.7	0.6	0.6	0.7	0.6	0.6
Sweet potatoes	3.0	3.0	2.9	3.2	3.1	3.2	3.0	3.0	3.0
Tobacco	30.1	25.3	26.5	24.5	21.3	23.6	22.0	16.0	24.3
Tung	6.8	7.7	4.8	4.5	2.4	1.6	2.0	3.0	4.1
Wheat	7.2	8.3	8.6	9.0	7.8	6.8	10.0	10.0	8.5

finally by truck to Coronel Oviedo. For 1972 we again used bagged fertilizer purchased on the U.S. Gulf Coast but shipped at tramp charter rates to Paranagua, Brazil, and then trucked to Coronel Oviedo. By at least 1975, fertilizer will be shipped in bulk through Paranagua to a bulk-blending plant at Coronel Oviedo. Cost estimates for the three situations were obtained from tables A-10 and A-14. Blending costs for the bulk-blending situation were obtained from table 67. For all three situations, costs were increased 15% to cover marketing expenses. Results are given in table 69.

The magnitude of crop response to fertilizer also enters into the calculation of economic returns. Research to date has been reported in section III and, for the crops studied, the response has been of the same order of magnitude as found in other countries of the world. Research plots, however, are more carefully tended than farmers' fields and harvest losses are held to a minimum. Since farmers, not researchers, must make the decision of whether to fertilize, we have chosen to make benefit/cost calculations under conditions as nearly resembling field conditions as possible. To this end, table 70 contains the yield response expected from the use of fertilizer and the amount of fertilizer that must be used to produce this response.

For five of the six crops considered, bagged fertilizers could be profitable but only if current (1971) costs were reduced about 20% -as is possible by shipping the fertilizer via tramp steamer to Paranagua. Nevertheless, farmers not accustomed to using fertilizers probably would not start using them because benefit/cost ratios still are too low. Not until bulk blends are available do the benefit/cost ratios become high enough for nonusers to adopt the new practice of fertilizing. Corn is an exception. Its value is so low that even bulk blends are too costly for high returns; however, a few innovators probably can make a profit from fertilizing this crop. Fertilization of wheat, without a double-crop of soybeans, is not profitable at present price relationships. Reducing bagged prices 20% is helpful but the soybeans still are necessary for fertilization to be very profitable. However, when bulk blends become available, wheat production should be a fairly profitable venture. Nevertheless, GOP must be careful, in controlling the price of the wheat, not to reduce the price below the current 10.7 ₲/kg.

Table 69. Estimated Cost to Farmers of Plant Nutrients at Coronel Oviedo for 1971, 1972, and 1975[a]

Year	N	P_2O_5	K_2O
		₲/kg	
1971	71.5	40.6	29.8
1972	54.3	32.9	23.9
1975 (bulk)	39.4	26.0	18.6

[a]See text for explanation of cost situations.

AGRICULTURAL CREDIT

At least three types of credit are needed if Paraguay is to expedite agricultural development through judicious use of lime and fertilizer. For the private sector to function in the greatly expanded role that is outlined here, it must expand its physical assets. Needed will be lime crushing equipment, bulk-blending plants, regional and local warehouses and sales offices, and equipment for servicing customers. Monies for these physical assets should be provided by BNF through medium- and long-term loans at attractive rates of interest. AID/Paraguay should consider the merit of a loan to BNF to support this aspect of the lime and fertilizer program.

When prime responsibility for fertilizer importation is shifted from BNF to the private sector, new methods of financing the imports will be needed. We have suggested above that private companies prepare to handle all imports within the next two years. BNF, with AID assistance, could establish a revolving fund for private industry to use for these imports. The establishment of bulk-blending plants will not affect the continuing need for such a fund.

The third type of credit that BNF would provide in the lime and fertilizer program would be production loans to farmers–but loans should not be made in kind. If a part of the loan is to be used for fertilizer, the amount should be determined by the farmer and his credit agent. A soil test report should be used as a basis for the kind and amount of fertilizer (or of lime) needed. The fertilizer salesman and the extension agent can also be involved to the extent the credit agent believes necessary for assurance that the farmer knows how to use fertilizer properly. The function of banks is to provide credit, not fertilizers, and the function of fertilizer companies is to provide fertilizer, not credit. If fertilizer companies are not relieved of this function, an additional charge must be placed on fertilizers.

We recommend that BNF, with or without the assistance of AID/Paraguay, provide monies for physical facilities needed to expand the lime and fertilizer industry, provide credit for private companies to import bulk fertilizers, and provide production credit to farmers.

PROMOTION AND EDUCATION PROGRAMS

Fertilizer companies in Paraguay already have agronomists on their technical staff and are using demonstrations to promote increased fertilizer use. The companies also use the FAV soil testing laboratory to determine the specific fertilizer needs of their customers' fields. When the industry converts from imported mixtures to bulk blends, the soil testing laboratory will become an even more important tool in a company's promotion and education program. Bulk blending provides an opportunity to supply plant nutrients

Table 70. Benefit/Cost Ratios for Various Crops[a]

Crop	Year	Yield response	Fertilizer rate (N-P_2O_5-K_2O)	Yield value	Fertilizer cost	Benefit/cost ratio
		kg/ha		₲/ha		
Wheat-soybeans						
Wheat	1971	700	60-45-45	7,490	7,458	
Soybeans	1971	800	–	7,120	–	1.96
Wheat	1972	750	60-45-45	8,025	5,809	
Soybeans	1972	800	–	7,120	–	2.61
Wheat	1975	900	60-45-45	9,630	4,371	
Soybeans	1975	900	–	8,010	–	4.04
Wheat	1980	1,100	70-50-50	11,770	4,988	
Soybeans	1980	1,000	–	8,900	–	4.14
Tobacco	1971	1,000	50-80-100	24,300	9,803	2.48
	1972	1,000	50-80-100	24,300	7,737	3.14
	1975	1,000	50-80-100	24,300	5,910	4.11
	1980	1,000	50-80-100	24,300	5,910	4.11
Cotton	1971	1,350	80-40-55	21,195	8,983	2.36
	1972	1,350	80-40-55	21,195	6,974	3.04
	1975	1,650	80-40-55	25,905	5,215	4.97
	1980	2,050	100-45-65	32,185	6,319	5.09
Corn	1971	2,300	80-40-55	11,730	8,983	1.31
	1972	2,300	80-40-55	11,730	6,974	1.68
	1975	2,500	80-40-55	12,750	5,215	2.44
	1980	3,000	100-45-65	15,300	6,319	2.42
Rice	1971	2,100	60-40-40	22,260	7,106	3.13
	1972	2,100	60-40-40	22,260	5,490	4.06
	1975	2,400	60-40-40	25,440	4,148	6.13
	1980	2,600	60-40-40	27,560	4,148	6.64
Sugarcane	1971	45,000	100-50-65	27,000	11,117	2.43
	1972	45,000	100-50-65	27,000	8,629	3.13
	1975	45,000	100-50-65	27,000	6,449	4.19
	1980	45,000	120-55-80	27,000	7,646	3.53

[a]Based on estimated fertilizer costs at Coronel Oviedo.
[b]The government-controlled price of 10.7 ₲/kg was used rather than the 8-year average price.

in the exact quantities specified by the soil test results rather than the approximate quantities that result from the use of bagged mixtures.

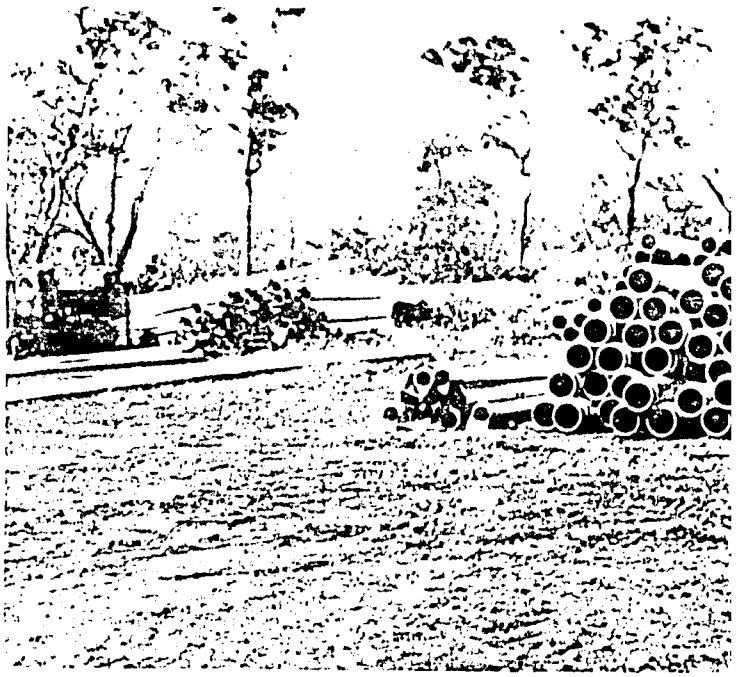
Expanded fertilizer use will cause expansions in all aspects of the fertilizer industry and in many peripheral areas. More fertilizer salesmen will be needed, extension agents will be contacted more frequently with questions about fertilizers, credit fieldmen will need to know more about how fertilizers should be used, men must be trained to operate and work in bulk-blending plants, and researchers at FAV and the MinAg experiment stations must become familiar with the new methods of handling and applying fertilizer in bulk. Above all, many farmers must be taught how to use fertilizer economically and effectively. The MinAg already has conducted some farmer short courses and is planning short courses for agricultural extension agents. For a viable lime and fertilizer use program, these efforts should be expanded.

We recommend that a series of short courses be planned and conducted for the various groups that will become involved in the production, marketing, and use of lime and fertilizer. We suggest that AID/Paraguay, in cooperation with the local fertilizer industry, BNF, and MinAg, arrange to send a team of three to five men to the United States to study fertilizer production, marketing, and use in general and bulk blending in particular. This visit should be scheduled for April and May of 1971 in order to visit bulk-blending plants while they are operating. (Many bulk-blending plants in the United States operate only during the spring planting season, hence the visit must be timed for this period.) This team—or a similar team—should also attend an AID short course in fertilizer production,

marketing, and use that is conducted by TVA's National Fertilizer Development Center and includes study at North Carolina State University. This course is intended to train participants to return to their country to conduct short courses for their coworkers and others.

Within the country, short courses should be conducted to provide extension workers and industrial agronomists with the latest information on lime and fertilizer needs. The discussions should consider the various crops and soils of the country, research results with lime and fertilizer, new varieties and their response to fertilizers, technique of communicating with farmers, and many other topics. At the request of AID, TVA's National Fertilizer Development Center has prepared a handbook that can be used in designing and conducting short courses (14). The National Fertilizer Development Center, working through AID, can provide personnel to help in designing short courses and also can provide teachers for those areas of instruction where local people do not have sufficient technical knowledge to act as instructors.

Additional comments on training of personnel are given in the section on Quality Standards for Lime and Fertilizers.



Long-term loans for irrigation and other equipment should be broadened to include corrective lime and fertilizer.

INCENTIVE PROGRAMS

Incentive programs to promote fertilizer use must always be considered when the cost of fertilizer is high. There are two broad approaches to incentives: maintain the price of fertilizer at low levels or support crop prices at high levels—with low and high being relative terms. Many countries seek to keep prices of staple foods at low levels so that low-income urban dwellers can make some purchases. Fertilization of these crops is rarely profitable, regardless of the subsidy given to fertilizer, and much of the fertilizer ultimately is used on crops with high benefit/cost ratios. In other countries, prices of staple crops are supported at levels high enough to encourage fertilizer use and to increase indigenous production of the crop. This procedure encourages increased use of fertilizer which, in turn, tends to reduce fertilizer costs. As the fertilizer costs are reduced, the support price of the crop also can be reduced until the price is approximately that of the world market. We recommend that GOP support the price of crops (especially wheat) rather than subsidize the cost of fertilizer. For most crops that are exported, benefit/cost ratios will be satisfactory when bulk-blended fertilizer is available. For wheat, which must be imported, world prices are too low for a satisfactory fertilizer benefit/cost ratio in Paraguay. GOP has been supporting the price at slightly above the world market—the current support price is 10.7 ₲/kg—and this price is just adequate to encourage fertilizer use.

There are additional measures that can be used to promote agricultural development and GOP has adopted some of these. We refer to two broad categories of actions. In the National Wheat Program, farmers who agree to plant 100 ha or more are able to obtain 100% loans for land purchase and clearing, agricultural machinery (including irrigation systems), and fertilizers. The fertilizer loan is a short-term loan of 8-9 months with an annual interest rate of 10%; lime is neither included nor excluded for consideration as a part of the fertilizer loan. Many of the fields cleared for wheat production, or reclaimed from abandoned agriculture, have failed to respond to treatment. The investment in these fields—as cost of land, land clearing, fencing, and management time—results in a high total investment per unit area. When part of the land fails to produce, an extra burden is placed on the remaining hectarage to repay the entire loan. Although it may be argued that there is adequate hectarage elsewhere that could be selected to fill out a management unit, the argument is without merit. The road system is too poor and sparse to permit ready transfer of equipment and machinery for any considerable distance.

We recommend that the original capital investment loan for farmers be broadened to include the initial application of lime needed to correct the extreme acidity of many soils and to include a corrective application of phosphate and potash fertilizer. Subsequent applications of lime, at approximately 3-year intervals, and annual applications of nitrogen and other fertilizer nutrients would not qualify for

the long-term capital investment loan but would be handled as are current fertilizer loans. The cost of this type of incentive would be negligible but would improve loan repayments and provide additional assurance of GOP's long-term interest in wheat production.

A second area in which GOP already has taken some action but again has not gone as far as possible concerns customs and duties on agricultural inputs. Many of these already have been liberated and reduced to reasonable levels but a few seem to have been overlooked. Fees for Brazilian trucks hauling fertilizer into Paraguay seem unreasonably high. Each of these trucks must pay a fee of $50 when entering Paraguay, as well as posting a large bond to guarantee departure of the truck. Many of these trucks haul only 10 mt and this fee is equivalent to $5/mt of fertilizer; consequently, it makes up a sizable portion of the total cost of fertilizer. Elimination of all or most of this fee would be most helpful. (This fee was brought to the attention of the Minister of Agriculture before the TVA team departed Paraguay. We understand that this fee is no longer charged.) Truckers also comment that they frequently spend many hours waiting to clear customs and inspections—although clearance can be expedited by paying extra fees. These extra fees or lost-time waits add to the total cost of fertilizers.

We recommend that GOP reveiw its customs and duties on fertilizers and again eliminate and reduce as many as possible; further, efforts should be made to expedite the orderly movement of fertilizer into the country.

OTHER SERVICES

A broad range of services can be offered by a fertilizer company genuinely interested in establishing a reputable name. Foremost among these services should be an adequate supply of the kinds of fertilizers that farmers need, available at the time they need them. To anticipate changing needs, the manager of fertilizer sales and the company agronomist must keep informed of new research results, new fertilizers, and marketing changes. Much of this information can be passed on to farmer customers as a part of the company's technical or educational program.

Fertilizer salesmen and the company agronomist also should be as nearly familiar with customers' fields as are the farmers themselves. New varieties, the need for herbicide and insecticide treatments, changes in fertilizer ratios and rates, and new farming techniques should be brought to their customers' attention in various ways. Some of these ways are demonstrations, personal conferences, group meetings, and the mass media. These intangible services are a valuable part of a company's service program and a country's educational program.

We recommend that all companies perform educational services and that government officials cooperate in supplying needed information to company officials.

We mentioned earlier that fertilizer companies could acquire bulk spreaders either for rent to customers or for custom applications. Many companies in the United States are going several steps farther and are organizing agricultural service centers. At one location a farmer is able to purchase all the inputs that he needs for his farming operations—and also to arrange for a loan from his bank. These service centers stock fertilizer seeds, agricultural chemicals, petroleum products, tires and batteries, feeds, livestock supplies, hand tools, and many other items. Application equipment for fertilizers and agricultural chemicals can be rented or custom application can be hired. A telephone call results in delivery of needed supplies or equipment directly to the farm. We do not recommend that similar service centers be established throughout Paraguay but enterprising fertilizer companies may want to do more than just sell fertilizer.

FERTILIZER AND LIME USE—TECHNOLOGY AT THE FARM LEVEL

The farmer, perhaps more than anyone else, is well aware of the fact that proper use of fertilizer requires careful integration of a number of management factors. Not only must he be sure he is purchasing the most suitable forms of fertilizer and lime for the particular soil fertility conditions of his fields, but he also must coordinate this purchase with his planting schedule, the particular placement and timing of application for the crop being grown, and the mechanism of application itself (whether by hand or with mechanical equipment). All of these factors are again brought up for consideration if the farmer switches from one kind of handling to another—such as from bagged to bulk materials. The following section describes in some detail the most important management consideration involved in an orderly development of fertilizer and lime use at the farm level. These considerations will, in turn, affect the development of fertilizer and lime supply and distribution systems.

Fertilizer Placement

The soils of the important agricultural areas of Paraguay are predominantly acid; most will require lime in the management practice. A more complete treatment of liming considerations is given in section V. From the standpoint of fertilizer placement, soils reduce the feasibility of broadcasting the fertilizer uniformly over the soil surface. Phosphorus fixation is more pronounced when phosphorus is applied broadcast than when it is applied in bands or placed in the zone where the first plant roots develop.

Placing fertilizer within the immediate rooting zone requires that the fertilizer be applied during the planting operation. Several disadvantages are noted immediately with regard to simultaneous application of seed and fertilizer. The first of these is that, obviously, it complicates the planting operation, requiring that the fertilizer be on hand the exact moment planting is to be done and, more importantly, requiring mechanical equipment. Wide-row crops can be planted and fertilized by hand with a reasonable degree of placement precision, but close-planted crops such as cereals cannot be readily fertilized this way. Even where mechanical planting equipment is available, simultaneous application of seed and fertilizer requires good operators and equipment that runs with relatively few malfunctions, a situation which often does not prevail. In fact, some Paraguayan wheat growers who used mechanical planting and who applied fertilizer and seed simultaneously indicated that they had to employ three men to keep one planting unit running properly. Even then the fields had patches which did not receive uniform fertilization or seed.

A second problem of planting with simultaneous fertilizer placement is that only relatively low rates of fertilizer can be applied in some crops; otherwise, fertilizer damage to germination is likely to occur. This problem is especially common in soybeans. Most row-crop planters have side openers which keep the fertilizer two inches below and two inches to the side of the seed. These precise placement units increase the cost of the equipment, however.

These and other problems with precision fertilizer placement with respect to the seed have led many large growers to consider broadcast fertilization as a separate step during the land preparation process, despite the tendency for phosphorus fixation. A complete evaluation of phosphorus fixation is not available at this time for Paraguayan soils. Nevertheless, special research has been initiated to get this information. Preliminary results indicate fixation will not be serious on the majority of the wheat soils. Actual fixation of phosphorus in the most acid soils represents about 60% of that applied; on the soils with intermediate acidity, fixation represents about 30%-40% of that applied. These levels of fixation are similar to those in other soils of similar characteristics and are not severe enough to preclude the use of broadcast phosphorus in close-seeded crops.

Double-Crop Fertilization

The biggest user of fertilizer during the period 1971-1980 will be wheat and soybeans. These crops are often double-cropped on the same field, the wheat during the cold winter period and the soybeans immediately after the wheat is removed. In many parts of the world where soybeans are grown in rotation with a reasonably high value crop, all the fertilizer for both crops is applied to the first crop. This practice saves time in getting the soybeans planted and eliminates any danger of fertilizer burn on the soybean seed. At the same time, the amount of fertilizer carryover in phosphorus and potassium contributes favorably to the fertilizer requirement of the soybeans. Lack of nitrogen carryover is normally not important since soybeans are a leguminous crop.

The fertilizer needs calculated for wheat and soybeans have been made on the basis that all the fertilizer for both crops should be applied broadcast during the preparation of the seedbed for wheat (table 28). From the production point of view this will give slightly higher wheat yields and comparable soybeans yields. Another advantage is that all fertilizer can be handled in bulk and spread with a bulk spreader at a time when labor resources are less critical. Planting will be simplified since no fertilizer need be handled during the actual planting of either crop.

FIELD RESEARCH AND EXTENSION DEMONSTRATIONS

A rather large percentage of the field experiments in fertilizer use have been carried out on the several experimental stations and substations in Paraguay: FAV, Caacupe, San Juan Bautista (CREA), and Capitan Miranda. These experimental stations will continue to play a very important role in the research conducted by FAV and MinAg. However, the fertility of the soils on these stations has been modified considerably by the conservation-fertilizer practices employed over the years. As a result, the types of experiments carried out on the stations in the next decade should be carefully adapted to the soil fertility conditions encountered. For example, the very high level of phosphorus and potassium in some of the soils should be considered when applying these nutrients in future varietal work and fertilizer experiments. A series of laboratory and potted-plant studies has been designed to supply the basic data necessary to carefully plan each subsequent soil fertility field experiment on a year-to-year basis. A standard experimental design, such as has been imposed on all tests in the past, will no longer be suitable.

Experiments on farmers' fields will take on an increased importance. It will be necessary to move off the experimental stations in order to locate suitable soils for lime studies, phosphorus fixation and residual studies, and soil test correlation studies with a full range of soil fertility levels of phosphorus and potassium. The recent series of field trials conducted in the FAO program in Paraguay was a step in the right direction, since they will supply a considerable amount of soil test correlation information. However, maximum information cannot be obtained unless the levels of phosphorus and potassium are adjusted to the specific soil fertility condition of each experimental plot. This requires a soil analysis prior to site selection and

experimental design planning. In the event the FAO program is not in a position to handle four or five different kinds of experiments during one year, a suitable alternative would be to select a common soil fertility condition, say, low in both phosphorus and potassium, and install all the experiments on sites known to be deficient in both these nutrients.

Interpretation of experimental data should always be made with reference to the soil fertility level prevailing at the experimental site. The problem that results when the soil test level is not considered can be seen with potassium. Almost none of the fertilizer experiments conducted by MinAg were located on soils low in potassium. The lack of potassium response was noted and fertilizer formulas low in potassium have become the rule for large crop areas. Yet, the soil test summaries show rather extensive potassium deficiencies. The field experiments for the next crop season should purposely seek to establish some experiments on low potassium soils to gain information regarding the recommended levels of fertilization for this rather common condition.

The kind of experimental design itself should be changed for trials conducted by MinAg. A recommended set of treatments and designs has been outlined and is available in Spanish (39). This publication is available to all technicians working with soils and fertilizers in Paraguay.

Proper use of lime and fertilizer forms a very important part of a sound soil conservation program. Soils of Paraguay are rolling and rainfall can be heavy at times, leading to soil erosion problems which have been recognized by numerous workers (15). The conservation practices established on the experimental stations are impressive and very effective. Relatively few farmers have developed terraces which are as well defined as those on the experimental stations but at least one farm was visited where contour strips were being employed (Fortuna, Pedro Juan Caballero). The fertilizer projections for wheat and soybeans were made with the view to double-cropping these one year and to crop only wheat the next year. The potential erosion problems on rolling land make it unadvisable to double-crop every year unless a special practice of no-tillage could be worked out. A no-tillage practice could have an important effect on the economics of double-cropping if the rather complex management scheme can be handled. Essentially, no-tillage wheat-soybean production would involve rather conventional land preparation, liming, and fertilization. After the wheat harvest, however, a no-tillage soybean planter would be used to plant in the unplowed wheat stubble. Weed and insect control must be done chemically. A special planter is required but the no-tillage aspect offsets this expense. The planting efficiency of the soybean crop would be improved considerably, especially if the plan to bulk spread all fertilizer prior to the wheat crop were followed. The relatively sandy texture of most wheat soils in Paraguay favors the no-tillage practice since actual planting can be done over a wider range of moisture conditions. The effect of no-tillage second-cropping would provide a very substantial benefit to the soil conservation program and reduce soil fertility losses due to erosion.

Much applied research is needed with fertilizers in Paraguay. Since most of the fertilizer will be used on wheat for the next several years, it is on this crop that the research should be conducted first. This has a number of advantages. Many of the wheat producers are ingenerio agronomos and can help with the research. The demonstrations that ordinarily would be needed to show research results to farmers will not be needed for these wheat farmers; they (along with extension agents) will learn directly from the research plots. In 2 to 3 years, enough research will have been completed on wheat (and perhaps another crop or two as well) that demonstrations can be started. This time schedule fits well with the short course schedule discussed earlier and with the general availability of blended fertilizer.

We recommend that fertilizer demonstrations be postponed until the extension staff has gained more knowledge about and experience with fertilizers and research personnel have completed more applied research.

BASIC SOIL FERTILITY RESEARCH THROUGH LABORATORY AND POTTED-PLANT STUDIES

The studies outlined below are urgently needed in order to provide basic information relating to soil fertility and use of fertilizer and lime. These studies are of short-term duration, low in cost, and within the research capability of the soils technicians at FAV. By putting priority into these projects, a proper foundation for soil analysis could be developed in a short time. The soil analysis base thus formed would provide an excellent and much improved backstop for the crop programs of particular interest in Paraguay. The soils laboratory is adequately equipped for routine soil tests; however, additional supplies and equipment are needed to support the applied research. These are listed in table A-20.

The soils to be included in all of these studies were obtained from key points visited by the TVA study team. They represent varying degrees of soil acidity and soil fertility. The origin of the soils is given in table 71.

In addition to serving for the seven experiments outlined below, each soil will be used as a control sample in the laboratory. The basic information gained from the studies can also be employed to design field experiments for all the experimental stations for 1971 as well as for selected farmers' sites.

Table 71. Summary of Soils Used for Basic Research Series

Soil	Origin	Comments
101	Experiment station, Misiones	site for 1971 experiments
102	Lichi farm, Misiones	zinc-deficient corn plots
103	German Colony, Capitan Miranda	field abandoned due to acidity
104	Experiment station, Capitan Miranda	site for 1971 experiments
105	Wheat field, Pedro Juan Caballero	acid spots - no wheat growth
106	Wheat field, Pedro Juan Caballero	poor wheat development
107	Wheat field, Puerto Presidente Stroessner	poor wheat spots
108	Experiment station, Caacupe	site for 1971 experiments
109	Experiment station, San Lorenzo	site for 1971 experiments
110	Wheat field, Curuguaty	poor wheat development

Brief Description of the Research Projects

Study No. 1

Short-term Study of Aluminum Tolerance of Five Important Wheat Varieties

Objective: A disturbing number of wheat fields in Paraguay indicates that germination and growth of wheat are adversely affected by soil acidity. In most cases the effect is probably due to the presence of exchangeable Al, the acid component of highly weathered mineral soils which is toxic to plants. Aluminum tolerance varies from crop to crop and, more importantly, from variety to variety. The immediate objectives of this study are to evaluate and rate five of the most important wheat varieties currently being grown in Paraguay with respect to their tolerance to Al. An additional part of the study will be to correlate the observed growth habit with Al analysis of the soils and to establish a tentative critical level of Al in soil above which that variety should not be recommended for planting.

Experimental Variables: 10 soils of varying acidity and Al analyses

5 wheat varieties - No. 214, 6, 9, 11, and 353/52

3 replications

The experiment will include 150 treatments and will be carried out in a potted-plant study.

Study No. 2

Short-term Study of Aluminum Tolerance of Five Soybean Varieties

The objectives, experimental variables, and treatments for this study are identical to those for the wheat study. Five important soybean varieties will be tested for Al tolerance. The soybeans will be planted in pots employed in the wheat study. The growth period will be that time required to demonstrate significant differences between varieties and soils.

Study No. 3

Lime Requirement and Correlation of Lime Requirement with Soil Analysis

Objective: The traditional procedure for determining lime requirement of soils has been to incubate acid soils to which varying rates of lime have been added so that a buffer curve can be measured. This curve indicates how much lime would be required to raise the pH of the soils to a given point, usually pH 6.0-6.5. However, soils of the tropics often do not need to be limed that heavily; in fact, liming beyond a pH of 5.5 has been observed to depress yields in neighboring countries where liming studies have been conducted. Therefore, there is a conflict of opinion among researchers regarding the lime requirement of soils. The more recent and popular view is that lime applications should be only large enough to reduce the toxic level of exchangeable Al to the point that the crops of interest to the area can be grown successfully (41).

The objectives of this study are several. First, an incubation study will be carried out for each soil to determine the buffer curve. The buffer curve will be related to different soil parameters, such as exchangeable Al, pH, cation exchange capacity, clay content, and organic matter.

The second part of the study will be a potted-plant investigation in which the lime requirement will be determined by plant response. Plant response to lime will be correlated with soil test data. If a good correlation can be obtained with a single soil test, such as exchangeable Al, or with several analyses, such as Al, organic matter, and clay content, then it should be possible to predict by means of soil tests how much lime should be applied.

Experimental Variables: 10 soils varying in acidity

4 rates of lime (no lime, lime to pH 5.5, lime to pH 6.0, and lime to pH 6.5)

2 fertilizer treatments: with and without micronutrients (Zn Mn, Cu, Fe)

2 replications

Study No. 4

Phosphorus Fixation and Residual Phosphorus Associated with Fertilization Rate, Time of Application, and Soil Analysis for P and Al

Objective: Evaluate the amount of applied P which is fixed in the soil and that amount which remains available as residual P as affected by rate of P application, length of time following application, and kind of P extractant employed to measure residual P.

Experimental Variables: 10 soils with varying P:K levels
5 lengths of incubation: 1/4, 2, 3, 8, and 16 months
5 rates of P application: 10, 20, 40, 80, 160 ppm P
3 soil P extractants: North Carolina, Bray P-1, Olsen
2 replications
Total of 1,500 observations

Study No. 5

Potassium Fixation and Residual Effect Associated with Fertilization Rates and Soil Analysis

Essentially this study will be carried out simultaneously with the P study, since the source of fertilizer employed for the five levels of P is KH_2PO_4. This gives application rates of approximately 12.5, 25, 50, 100, and 200 ppm K.

Study No. 6

Phosphorus Correlation Study to Relate Soil Phosphorus Availability to Plants with Several Modern Soil Tests

Objective: The procedure used for extracting P is the most critical in soil testing. The soil test must correlate well with plant response before a reliable prediction can be made for phosphate fertilizer needs. The objective of this study is to make such a correlation between plant response to fertilizer P and several modern soil tests for P.

Experimental Variables: 30 soils–10 of the original acid soils with native level P, 10 soils from same origin but with higher levels of P and pH about 6 (soils employed in previous potted-plant studies), 10 soils from sites unrelated to the original group of acid soils

2 fertilizer treatments: without P, with 50 ppm P, (or higher for infertile soils showing high fixation–Study No. 4)

3 replications

Study No. 7

Potassium Correlation Study to Relate Soil K Availability to Plants with Several Modern Soil Tests

In general, this study will be similar to Study No. 6 and will follow the techniques of the ISFE (57). However, only two levels of K will be employed: 0 and 50 ppm K.

QUALITY STANDARDS FOR LIME AND FERTILIZERS

Limestone

Two factors determine the liming value of crushed rock: chemical composition and fineness of grinding. As reported in other sections of this report, the northern quarries can provide both calcitic and dolomitic limestone. Dolomitic limestone has a greater neutralizing effect, per unit weight, than calcitic limestone; in addition, many of the soils need the magnesium that is an essential component of dolomite. Thus, northern quarries can produce both kinds of lime but the farmer has no way of knowing which he receives. He must rely on the reputation of the producer and any intermediate handlers not to make errors. The central deposits present a different problem regarding quality. Here there are three strata of limestone, two of which contain some phosphorus in accessory amounts. Presumably the phosphatic limestone is worth more than the nonphosphatic limestone. If so, farmers should be able to determine that they have, indeed, received the exact material they purchased.

Still another chemical problem is likely to arise with the central deposits and possibly with the northern and southern deposits as well. This problem deals with the actual purity of the limestone. In central Paraguay, the limestone outcrops on hillsides but in the southern and northern areas the rock is mined from pits. In all cases, the overburden of soil and sand is stripped off before the rock is mined and crushed. If some of this overburden were to find its way into the crusher, it could not be detected without a chemical analysis. This type of adulteration is deliberate. On the other hand, there are also many lenses of silica and clay in some of the limestone strata. It is virtually impossible to remove these from the lime before crushing. Diminution of the calcium carbonate content by inclusion of this material may be a practical necessity but the price of the limestone should be reduced to reflect its actual purity. Without the necessary laws and regulatory authority and without a laboratory to determine the chemical composition of various limestones, farmers and legitimate producers will have no protection against accidental or deliberate diminution of the chemical quality of limestone.

From a quality standpoint, fineness of grinding is as important as chemical composition. Without official specifications on fineness of grinding, a dealer theoretically could deliver an order for one ton of limestone as a single boulder. At the opposite extreme, one of the prospective lime producers was advised that he must order crushing and sieving equipment that would enable him to crush all material until it passed through a 10-mesh screen. Further, the material was to be passed over a 100-mesh screen and the two fractions collected separately. No reason was given for this second screen and no suggestions were made concerning the relative value of the two differently sized fractions. Since it is cheaper to produce coarse limestone, producers should not be required to crush the material to unnecessary fineness. Again, without regulatory authority and the necessary analytical apparatus, there is no way of knowing whether producers are crushing the rock to the recommended or official degrees of fineness.

Both chemical composition and fineness of grinding determine the neutralizing power of an agricultural limestone. That is, materials of very high purity but rather coarsely ground may have the same neutralizing power as limestone of lower purity but much finer grinding. Insofar

as use on an acid soil is concerned, the two materials are of equal value. Thus, a quality scale that combines both chemical composition and size distribution of the particles is needed.

We recommend the passage of laws that specify the minimum standards for chemical composition (calcium carbonate equivalent) and fineness of grinding for agricultural limestone, that define limestone quality or neutralizing power in terms of both chemical composition and fineness of grinding, and that specify penalties for mislabelling of limestone as to quality.

Regulatory activities normally are carried out by a group of field inspectors who collect samples and by an official laboratory which performs the physical and chemical analyses. The equipment used in collecting samples and the techniques for taking representative samples should be prescribed carefully and field inspectors should be trained thoroughly for their jobs. Laboratory procedures and personnel are equally important.

We recommend that the head of the laboratory services and the chief inspector be sent to the United States to study techniques and procedures. This study tour should start just as soon as possible and should be for about 3 months. Possible study locations are Louisiana State University, Baton Rouge; Purdue University, Lafayette, Indiana; and Missouri State University, Columbia.

In the United States, regulatory activities are a function of the state government. In some states, the laboratories are associated with the agricultural university and the employees frequently have joint appointments between the state department of agriculture and the university. In other states, the laboratories are located at the state capitol and have no formal association with the university. Since the function of these laboratories and inspection services is strictly regulatory, we believe they should be under the complete control of a government agency.

We recommend that the laboratories and inspection services for agricultural limestone be under the control of and operated by the MinAg.

There is a degree of urgency in establishing the limestone regulatory services. Some of the quarries expect to be in production by June 1971. Operators need to know what specifications will be imposed upon their product so that they can purchase the necessary equipment. Unfortunately, no research has been reported on the rate of solution of various size fractions of calcitic and dolomitic limestone in various Paraguayan soils. Codas has made some studies of limestone quality and has initiated studies to determine the lime requirement of soils (24, 25). Until the results of these and additional studies are completed, Paraguay probably should use the standards that have been set up in other countries with similar soils or even those used in the United States.

Fertilizer

Fertilizer production is not planned for Paraguay and it might seem unnecessary to establish inspection and regulatory services. However, we have recommended that fertilizers be handled in bulk just as soon as possible and have given major emphasis to bulk blending. Any time two or more ingredients must be mixed, there exists a chance for errors. Whenever some of the ingredients are more valuable than others, there is the further possibility that someone will deliberately reduce the input of the high-value ingredients. On the other hand, when a farmer fails to obtain the growth or yield he expects from a crop, he frequently blames one of his purchased inputs rather than poor management. Many of these problems can be avoided and others can be answered satisfactorily when official samples are collected and analyzed.

We recommend the passage of laws that define commercial fertilizers and establish the standards of quality that shall be enforced upon all handlers. The Association of American Fertilizer Control Officials annually publishes its latest draft of a uniform state fertilizer bill. The bill is based on more than one hundred years of inspecting samples of commercial fertilizer in the United States. Each term and provision in the bill has been carefully studied before inclusion. Copies of the bill can be obtained from: Secretary, Association American Fertilizer Control Officials, Department Biochemistry, Purdue University, Lafayette, Indiana 47906.

As with limestone samples, the collection techniques and equipment and analytical procedures must be carefully prescribed. There is no universal agreement on the best procedures to use but Paraguay undoubtedly will purchase fertilizers on the world market. Fewer difficulties would be experienced if the procedures were very similar or identical to some of those already in use rather than entirely different. The uniform fertilizer bill does not specify the procedures that are used to collect and analyze fertilizer samples. Official analytical procedures in the United States are developed by the Association of American Fertilizer Control Officials and are available in published form (38).

We recommend that a team visit the United States and other countries in Latin America to study the procedures used and to recommend those that will best serve Paraguay.

Although we have treated limestone regulatory services separately from fertilizer regulatory services, it would be expedient for a single laboratory and field inspection unit to serve in both capacities. The team composed of the head of the laboratory services and the chief inspector, therefore, would study both lime and fertilizer procedures. This team should then add the North Carolina State Department of Agriculture, Raleigh, and the South Carolina State Department of Agriculture, Clemson, to its study tour.

We recommend that the laboratories and inspection services for fertilizer be under the control of and operated by the MinAg.

MINERAL RAW MATERIALS FOR AGRICULTURAL USE

Although no igneous rocks rich in apatite were observed during this brief investigation, it cannot be said that none will be found. Careful investigation by detailed geological mapping, magnetic surveys, radioactivity surveys, heavy mineral surveys, and geochemical soil sampling of alkalic igneous rock complexes such as those near Sapucai and Acahay may reveal commercially valuable concentrations of minerals containing phosphorus, niobium, copper barium, strontium, thorium, uranium, and rare earths. The new topographical maps being prepared by the Military Geographic Institute and Interamerican Geodetic Survey will make excellent base maps for detailed geological mapping.

We recommend that the work begun at Sapucai be continued in a more detailed manner. The Acahay-La Colmena area should be investigated before returning again to the Sapucai area.

The limestone along the Paraguay River between Itapucumi and Vallemi is ample to meet the needs of Paraguay almost indefinitely. Its location with respect to the agricultural areas, however, limits its economic usefulness in agriculture. The location of deposits in each of the three main agricultural areas, then, is of immediate and major importance to the continued development of agriculture. Present knowledge of these deposits is very inadequate. The deposit in the northern zone, at Pedro Juan Caballero, was not visited. Its mineralogical nature, geological nature, and extent is not known. In the central zone the limestone occurs as a sedimentary deposit with some phosphate in two of the strata. The southern deposit, at Villa Florida was located but the only known exposure was temporarily underwater and could not be adequately sampled. The extent of reserves in this area also is unknown.

We recommend that the extent and nature of the limestone deposits in each of the three agricultural zones be fully explored.

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APPENDIX

Table A-1. Soil Test Results for Available Phosphorus and Available Potassium in Eastern Paraguay (35)

Agricultural zone & district	Number of samples	Percentage of soils deficient in[a]		
		Both P & K	P only	K only
Northern				
Amamby	210	56	27	4
Concepcion	270	45	40	2
San Pedro	463	76	20	4
Mean	943	63	27	3
Central				
Alto Parana	127	28	60	1
Caaguazu	472	53	41	1
Caazapa	130	50	44	2
Central	411	36	32	6
Cordillera	284	43	42	3
Guaira	89	35	62	0
Paraguari (½)	180	33	57	1
Mean	1,693	42	43	2
Southern				
Itapua	354	26	62	3
Misiones	532	53	43	1
Neembucu[b]	–	–	–	–
Paraguari (½)	180	33	57	1
Mean	1,066	40	52	3
Weighted mean	3,702	47	42	3

[a]Percentages do not total to 100 because a few soils contain medium to high amounts of available P and K.
[b]Insufficient data.

Table A-2. Soil Test Results for Soil Acidity in Eastern Paraguay (35)

Agricultural zone & district	Number of samples	Percentage of soils in each pH range			
		< 5.0	5.1–5.5	5.6–6.4	≥ 6.5
Northern					
Amamby	210	51	20	18	11
Concepcion	270	20	16	34	30
San Pedro	463	30	30	28	12
Mean	943	32	24	27	17
Central					
Alto Parana	127	32	28	25	15
Caaguazu	472	27	28	32	12
Caazapa	130	44	18	24	14
Central	411	16	28	41	15
Cordillera	284	35	27	30	6
Guaira	89	41	17	39	3
Paraguari (½)	180	18	33	40	9
Mean	1,693	27	27	34	12
Southern					
Itapua	354	28	18	30	24
Misiones	532	26	32	38	4
Neembucu[a]	–	–	–	–	–
Paraguari (½)	180	18	33	40	9
Mean	1,066	25	28	36	11
Weighted mean	3,702	28	26	33	13

[a]Insufficient data.

Table A-3. Hectarage of Principal Crops in Eastern Paraguay in 1969 (51)

Agricultural zone & department	Wheat	Cotton	Tobacco	Corn	Rice	Sugarcane	Vegetables[a]
				ha			
Northern							
Amamby	2,500	100	640	1,900	–	280	60
Concepcion	2,650	1,800	960	4,300	–	510	50
San Pedro	5,470	1,700	1,950	8,400	480	480	80
Subtotal	10,620	3,600	3,550	14,600	480	1,270	190
% of total	33.6	6.0	17.8	11.4	4.7	5.4	5.8
Central							
Alto Parana	190	300	1,350	2,600	–	90	100
Caaguazu	3,200	7,600	2,060	17,200	220	2,120	420
Caazapa	960	4,000	1,100	9,200	260	1,140	540
Central	410	2,500	1,150	5,900	325	4,130	330
Cordillera	2,500	5,700	2,710	11,800	1,800	1,500	270
Guaira	570	2,800	1,750	9,800	290	4,310	180
Paraguari (½)	2,490	6,800	1,380	12,250	365	2,410	205
Chaco[b]	1,450	3,200	520	500	–	2,020	140
Subtotal	11,770	32,900	12,020	69,250	3,260	17,720	2,185
% of total	37.2	54.8	60.1	54.3	31.8	75.6	66.2
Southern							
Itapua	1,590	11,700	1,380	20,900	3,500	1,220	310
Misiones	4,970	2,200	970	8,000	2,600	480	280
Neembucu	160	2,800	700	2,500	40	350	130
Paraguari (½)	2,490	6,800	1,380	12,250	365	2,410	205
Subtotal	9,210	23,500	4,430	43,650	6,505	4,460	925
% of total	29.2	39.2	22.1	34.3	63.5	19.0	28.0
Total	31,600	60,000	20,000	127,500	10,245	23,450	3,300

[a]Sum of the area for onions and potatoes only.
[b]The Chaco is included in the central zone because all supplies for this area must come through the central zone.

a\

Table A-4. Mineralogical Characterization of Limestone Samples

X-ray Determination of Carbonates[a]

Location and sample nos.

	Villa Florida						Vallemi					Itapucumi								Itacua			Coronel Oviedo-Caaguazu stratigraphic series																
	1	2	3	4	5	6	7	8	9	WS	GB	10	11	12	13	14	15	16	CC	17	18	19	20	21	22	23	24	25	26	27	28	28A	29	30	31	32	33	34	40
Calcite	M	m	m	m	m	m	m	m	m	m	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
Dolomite		M	M	M	M	M	M	M	M	M	m	x	x	m	x	x	m	x	x				x	x	x		m	m	x	m		m	m		x	x	x	m	x

Petrographic Determination of Noncarbonates[b]

	1	2	3	4	5	6	7	8	9	WS	GB	10	11	12	13	14	15	16	CC	17	18	19	20	21	22	23	24	25	26	27	28	28A	29	30	31	32	33	34	40
Quartz (granular)	30	100	20	5	5	2	70	85	85	95	80	55	60	90	30	80	30	80	25	70	80	25	70	5	70	70	70	65	65	50	20	30	15	80	10	40	75	60	30
Opal-chalcedony	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	25	–	90	–	2	–	–	–	25	60	50	80	5	60	40	10	–	50
Feldspars	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5	–	10	5	5	5	15	20	15	10	3	5	8	15	10	10	5
Diopside, $CaMg(SiO_3)_2$	70	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Muscovite-Biotite	–	–	–	–	–	–	30	15	15	5	10	–	–	–	30	15	10	10	–	30	20	25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Goethite, $Fe_2O_3 \cdot H_2O$	–	–	–	–	–	–	–	–	–	–	–	–	–	5	20	5	10	10	–	–	–	–	10	5	10	10	10	10	10	–	5	10	–	10	2	5	2	2	10
Limonite, $Fe_2O_3 \cdot xH_2O$	–	–	–	–	–	–	–	–	–	–	–	P	5	10	–	–	–	–	–	–	–	–	–	P	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Chlorites-vermiculites	–	–	80	90	95	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Clay minerals	–	–	–	–	–	–	–	–	–	–	10	35	35	–	10	–	20	–	–	–	–	25	15	–	10	13	15	20	10	–	–	–	2	–	–	–	–	28	5
Fluorite, CaF_2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	30	–	75	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Brucite, $Mg(OH)_2$	–	–	–	–	–	98	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Apatite (francolite)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	P	P	P	P	–	P
Accessory minerals	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5	–	–	–	–	–	–	3	–	–
Carbonaceous matter	–	–	–	–	–	–	–	–	–	–	–	10	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Wt % in sample[c]	64.0	1.5	2.0	25.0	18.0	14.0	9.6	8.4	8.4	18.0	10.0	4.6	11.0	1.0	0.7	0.3	2.4	0.8	0.4	4.0	0.6	10.7	17.0	56.5	14.0	18.5	15.0	9.9	12.0	57.0	52.0	37.0	53.5	45.0	54.0	22.0	52.0	65.2	5.5

[a](M) = major type; (m) = minor type; (x) denotes an amount below X-ray detection limits, but identified during microscopic examination.
[b]Numbers denote relative abundance of mineral groups in noncarbonate mineral fraction of head sample. (P) = present before extract.
[c]Total weight % of noncarbonate mineral fraction in head sample; carbonates removed by decomposition in 2% acetic acid.

Table A-5. Chemical Characterization of Limestone Samples

Location and sample nos.

Constituent	Villa Florida 1	2	3	4	5	6	Vallemi 7	8	9	WS	GB	Itapucumi 10	11	12	13	14	15	16	CC
										Wt %									
CaO	19.8	32.9	34.1	31.1	33.2	34.1	31.6	32.5	34.0	31.9	48.4	52.9	49.1	53.1	55.4	55.4	54.2	55.3	55.6
MgO	2.5	18.6	17.3	14.0	11.4	20.8	14.1	14.4	13.2	11.9	1.7	0.2	0.2	2.0	0.2	0.1	0.6	0.2	0.1
CO_2[b]	14.9	46.0	45.3	34.1	37.1	39.1	(40.1)	(41.2)	(41.1)	(36.4)	(39.8)	(41.7)	(38.7)	(43.7)	(43.7)	(43.5)	(43.0)	(43.6)	(43.8)
SiO_2	–	–	–	–	–	–	–	–	–	–	–	2.8	6.9	0.8	0.4	0.1	1.0	0.2	0.1
H_2O (105° C)	0.7	0.1	0.1	0.6	0.1	0.7	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.1	0.1	0.1	0.1	0.1	0.1
Ign. loss (900° C)	16.8	45.7	45.2	37.5	38.3	43.2	40.5	41.2	41.2	37.4	39.9	41.6	39.3	43.3	43.3	43.2	43.0	43.5	43.6
Organic + H_2O	1.2	0.1	0.1	2.8	1.1	4.1	(0.4)	(0)	(0.1)	(1.0)	(0.1)	(0)	(0.3)	(0)	(0)	(0)	(0)	(0)	(0)
Wt % gangue[c]	64.0	1.5	2.0	25.0	18.0	14.0	9.6	8.4	8.4	18.0	10.0	4.6	11.0	1.0	0.7	0.3	2.4	0.8	0.4

Location and sample nos.

Constituent	Itacua 17	18	19	Coronel Oviedo-Caaguazu stratigraphic series 20	21	22	23	24	25	26	27	28	28A	29	30	31	32	33	34	40
										Wt %										
CaO	53.0	55.6	49.7	46.2	22.3	47.8	45.6	47.0	49.5	48.7	23.6	26.5	34.5	25.7	30.1	25.3	43.2	26.6	18.4	52.4
MgO	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.5	0.7	0.2	0.3	0.1	0.5	0.2	0.1	0.1	0.1	0.2	0.9	0.1
CO_2[b]	(41.6)	(43.7)	(39.0)	(36.4)	(17.7)	(37.6)	(35.8)	(37.6)	(39.6)	(38.4)	(18.9)	(20.8)	(27.7)	(20.4)	(23.6)	(20.0)	(34.1)	(21.0)	(15.5)	(41.1)
SiO_2	2.9	0.4	7.8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
H_2O (105° C)	0.1	0.1	0.8	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.2	0.3	0.5	0.2	0.1	0.2	0.9	0.2
Ign. loss (900° C)	42.7	43.3	40.3	36.2	19.9	37.5	35.7	37.2	39.4	39.1	19.1	20.9	27.6	20.4	24.5	20.3	34.1	21.0	15.4	40.6
H_2O and organics	(1.1)	(0)	(0.5)	(0)	(2.0)	(0)	(0)	(0)	(0)	(0.7)	(0.2)	(0.1)	(0)	(0)	(0.4)	(0.1)	(0)	(0)	(0)	(0)
P_2O_5	–	–	–	0.04	0.03	0.03	0.06	0.04	0.03	0.03	0.04	0.07	0.06	0.05	0.20	0.07	0.12	0.20	–	0.40
Wt % gangue[d]	4.0	0.6	10.7	17.0	56.5	14.0	18.5	15.0	9.9	12.0	57.0	52.0	37.0	53.5	45.0	54.0	22.0	52.0	65.2	5.5

[a]CaO and MgO determined on dilute HCl extract of carbonates; MgO from chlorite-vermiculite contributes 5.1% in sample 4, and 1.3% in sample 5.
[b]Values in ( ) calculated from the amounts of carbonate materials in head sample.
[c]This value for total SiO_2, as determined by $HClO_4$ decomposition precedure, is too low; value should be about 0.6%-0.7%.
[d]Total Wt % of gangue minerals (noncarbonate group) determined from residues after extracting carbonates with 2% acetic acid at 25° C for 12-18 hours (see table A-4).

Table A-6. Maintenance Lime Requirements

Crop	Time period	Projected rate of nitrogen	Lime requirement Annual	Lime requirement 3 years
			kg/ha	
Wheat	1971-75	60	480	1,440
	1976-80	70	560	1,680
Corn	1971-75	80	640	1,920
	1976-80	100	800	2,400
Vegetables	1971-72	80	640	1,920
	1973-74	100	800	2,400
	1975-80	120	960	2,880
Tobacco	1971-80	50	400	1,200
Cotton	1971-75	80	640	1,920
	1976-80	100	800	2,400
Rice	1971-80	60	480	1,440
Sugarcane	1971-75	100	800	2,400
	1976-80	120	960	2,880
Tree crops	1971-74	100	800	2,400
	1975-80	120	960	2,880
Forages	1971	20	160	480
	1972	30	240	720
	1973	40	320	960
	1974	50	400	1,200
	1975-80	60	480	1,440

Table A-7. Projected Limestone Needs, 1971-1980

Year	Agricultural zone	Fertilized area	Area to be limed			Lime requirement		
			Initial	Maintenance	Total	Initial	Maintenance	Total
			ha			mt		
1971	Northern	9,705	9,705	0	9,705	11,646	0	11,646
	Central	14,880	14,880	0	14,880	16,070	0	16,070
	Southern	10,515	10,515	0	10,515	10,830	0	10,830
	Total	35,100			35,100			38,546
1972	Northern	12,855	3,150	0	3,150	3,780	0	3,780
	Central	21,142	6,262	0	6,262	6,763	0	6,763
	Southern	14,953	4,438	0	4,438	4,571	0	4,571
	Total	48,950			14,250			15,114
1973	Northern	16,005	3,150	0	3,150	3,780	0	3,780
	Central	27,505	6,363	0	6,363	6,872	0	6,872
	Southern	19,390	4,437	0	4,437	4,570	0	4,570
	Total	62,900			13,950			15,222
1974	Northern	19,995	3,990	9,705	13,695	4,788	15,862	20,650
	Central	34,997	7,492	14,880	22,372	8,091	27,900	35,991
	Southern	24,558	5,168	10,515	15,683	5,323	18,988	24,311
	Total	79,550			51,750			80,952
1975	Northern	24,940	4,945	3,150	8,095	5,934	5,355	11,289
	Central	44,100	9,103	6,262	15,765	9,831	12,865	22,696
	Southern	30,660	6,102	4,438	10,540	6,285	8,905	15,190
	Total	99,700			34,400			49,175
1976	Northern	30,000	5,060	3,150	8,210	6,072	5,355	11,427
	Central	53,702	9,602	6,363	15,965	10,370	13,118	23,488
	Southern	37,148	6,488	4,437	10,925	6,682	8,902	15,584
	Total	120,850			35,100			50,499
1977	Northern	35,900	5,900	13,695	19,595	7,080	22,478	29,558
	Central	64,235	10,533	22,372	32,905	11,376	42,910	54,286
	Southern	44,365	7,217	15,683	22,900	7,434	28,988	36,422
	Total	144,500			71,400			120,266
1978	Northern	41,890	5,990	8,095	14,085	7,188	13,518	20,706
	Central	75,167	10,932	15,765	26,697	11,806	30,972	42,778
	Southern	51,693	7,328	10,540	17,868	7,548	20,510	28,058
	Total	168,750			58,650			91,542
1979	Northern	44,630	2,740	8,210	10,950	3,283	13,805	17,093
	Central	82,930	7,763	15,965	23,728	8,384	32,472	40,856
	Southern	56,440	4,747	10,925	15,672	4,889	21,472	26,361
	Total	184,000			50,350			84,310
1980	Northern	47,635	3,005	19,595	22,600	3,606	32,188	35,794
	Central	91,635	8,705	32,905	41,610	9,401	63,662	73,063
	Southern	61,730	5,290	22,900	28,190	5,449	42,650	48,099
	Total	201,000			92,400			156,956

Table A-8. Estimated Capital, Variable, and Fixed Costs for Ordinary Superphosphate from a 212-mt/day Plant

Capacity

14,000 mt/yr as P_2O_5, or
70,000 mt/yr as OSP (0-20-0), or
212 mt/day as OSP for 330 days/yr

Capital Investment

Plant	$ 865,000
Working capital	1,689,000[a]
Total	2,554,000

Variable Costs

	Amount needed	Cost Unit	Cost Total
	unit/mt OSP	$/unit	$/mt OSP
Phosphate rock, 72% BPL (mt)[b]	0.627	43.49	27.27
Sulfuric acid, 93% (mt)[c]	.390	88.50	34.50
Electricity (kwh)	3	.05	.15
Water (1,000 gal)	1	.02	.02
Product loss, 1%			.68
Total variable cost			62.62

Fixed Costs

Operating labor[d]	.78
Maintenance, 5% of plant investment	.62
Supplies, 20% of maintenance	.12
Analyses, 20% of operating labor	.16
Overhead, 100% of operating labor	.78
Insurance, 2% of plant investment	.25
Depreciation (15 years)	.82
Handling, and storage of supplies, 4% of operating labor, maintenance, supplies, and analyses	.07
Return on investment, 10% of plant investment	1.24
Interest on working capital, 8%[e]	.97
Interest on plant investment, 8%[e]	.49
Total fixed cost	6.30

Total Cost of Production

	Bulk	Bagged[f]
	$/mt	
As OSP (0-20-0)	68.92	86.92
As P_2O_5	344.60	434.60

[a]Equivalent to the cost of raw materials for one month plus the value of production for 3 months.
[b]Phosphate rock imported from Florida with charges/mt as follows: F.o.b. mine, $5.50; freight to Buenos Aires, $8.50; freight and handling to Asuncion, $20.09; customs and other port charges, $9.40.
[c]Imported from Buenos Aires by rail at $73.50/mt plus $15.00/mt freight.
[d]Labor:

1 Supervisor/shift at $250/month	=	$ 250
3 Operator/shift at $75/month	=	225
3 Laborer/shift at $60/month	=	180
Shift cost/month	=	655
Monthly cost, 3 shifts, 3 x $655	=	1,965
Fringe benefit, 80% of shift cost	=	1,574
Overtime, 50% of shift cost	=	982
Total	=	4,521
Annual cost 12 months	=	54,252
Cost/mt OSP–70,000 mt/year		0.78

[e]Due to amortization, average annual rate is 4%.
[f]Cost of bagging is estimated at $18/mt, OSP.

Table A-9. Estimated Capital, Variable, and Fixed Costs for Sulfuric Acids

Capacity

(212 mt OSP/day x 0.39 mt 93% acid/mt OSP = 82.7 mt 93% acid/day)
82.7 mt 93% acid/day x 93% = 76.9 mt 100% acid/day
76.9 mt/day x 330 days/yr = 25,400 mt 100% H_2SO_4/yr

Capital Investment

Plant	$ 906,000
Working capital	355,000[a]
Total	1,261,000

Variable Costs

	Amount needed	Cost Unit	Cost Total
	unit/mt acid	$/unit	$/mt acid
Sulfur (mt)[b]	0.344	79.25	27.26
Cooling water (1,000 gal)	6.75	.02	.14
Electricity (kwh)	12	.05	.60
Boiler-feed water (1,000 gal)	0.18	.40	.07
Product loss, 1%			.42
Total variable cost			28.49

Fixed Costs

Operating labor, 0.75 man hours @ $2/man hour	1.50
Maintenance, 5% of plant investment	1.79
Supplies, 20% of maintenance	.36
Analyses, 20% of operating labor	.30
Overhead, 100% of operating labor	1.50
Insurance, 2% of plant investment	.72
Depreciation, (15 years)	2.38
Handling and storage of supplies, 4% of operating labor, maintenance, supplies, and analyses	.16
Return on investment, 10% of plant investment	3.57
Interest on working capital, 8%[c]	.56
Interest on plant investment, 8%[c]	1.43
Total fixed cost	14.27

Total Cost of Production

As 100% acid	42.76
As 93% acid	39.77

[a]Equivalent to the cost of raw materials for one month plus the value of production for 3 months.
[b]Sulfur imported with charges/mt as follows:

F.o.b. mine	$ 38.00
Ocean freight to Buenos Aires	8.50
Freight and handling to Asuncion	20.09
Customs and other port charges	12.66
Total	79.25

[c]Due to amortization, average annual rate is 4%.

Table A-10. Cost of Imported Fertilizers through Buenos Aires Via River to Paraguay through Asuncion

	Urea (45-0-0)				TSP (0-46-0)				KCl (0-0-60)				DAP (18-46-0)				$(NH_4)_2SO_4$ (21-0-0)			
	Bagged		Bulk		Bagged		Bulk		Bagged		Bulk		Bagged		Bulk		Bagged		Bulk	
	US	F	US	F	US	F	US	F	US	F	US	F	US	F	US	F	US	F	US	F
F.O.B. Gulf Coast	65.00	65.00	47.00	47.00	50.00	50.00	32.00	32.00	45.00	45.00	27.00	27.00	68.00	68.00	50.00	50.00	27.00	27.00	9.00	9.00
Ocean freight	30.39	9.00	28.80	8.50	30.30	9.00	28.80	8.50	30.30	9.00	28.80	8.50	30.30	9.00	28.80	8.50	30.30	9.00	28.80	8.50
C.I.F. Buenos Aires	95.30	74.00	75.80	55.50	80.30	59.00	60.80	40.50	75.30	54.00	55.80	35.50	98.30	77.00	78.80	58.50	57.30	36.00	37.80	17.50
Ins. 0.2%	.19	.15	.15	.11	.16	.12	.12	.08	.15	.11	.11	.07	.20	.15	.16	.12	.11	.07	.08	.04
Port expense, Buenos Aires	5.85	5.85	3.07	3.07	5.85	5.85	3.07	3.07	5.85	5.85	3.07	3.07	5.85	5.85	3.07	3.07	5.85	5.85	3.07	3.07
River freight to Asuncion	17.02	17.02	17.02	17.02	17.02	17.02	17.02	17.02	17.02	17.02	17.02	17.02	17.02	17.02	17.02	17.02	17.02	17.02	17.02	17.02
C.I.F. Asuncion	118.36	97.02	96.04	75.70	103.33	81.99	81.01	60.67	98.32	76.98	76.00	55.66	121.37	100.02	99.05	78.71	80.28	58.94	57.97	37.63
Customs, 8.33%[a]	11.83	9.70	9.60	7.57	10.33	8.19	8.10	6.06	9.83	7.69	7.60	5.56	12.13	9.99	9.90	7.87	8.02	5.89	5.79	3.76
Stamps & fees	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Handling at customs	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13
Asuncion, total $/mt	138.32	114.85	113.77	91.40	121.79	98.31	97.24	74.86	116.28	92.80	91.73	69.35	141.63	118.14	117.08	94.71	96.43	72.96	71.89	49.52
Asuncion, $/mt nutrient	307.37	255.22	252.82	203.11	264.76	213.72	211.39	162.74	193.80	154.67	152.88	115.58	-	-	-		459.19	347.43	342.33	235.81
To Cnel. Oviedo																				
At Asuncion, total	138.32	114.85	113.77	91.40	121.79	98.31	97.24	74.86	116.28	92.80	91.73	69.35	141.63	118.14	117.08	94.71	96.43	72.96	71.89	49.52
Loading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Truck to Cnel. Oviedo	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Cnel. Oviedo, total $/mt	145.46	121.99	118.91	96.54	128.93	105.45	102.38	80.00	123.42	99.94	96.87	74.49	148.77	125.28	122.22	99.85	103.57	80.10	77.03	54.66
Cnel. Oviedo, $/mt nutrient	323.24	271.09	264.24	214.53	280.28	229.24	222.57	173.91	205.70	166.57	161.45	124.15	-				493.19	381.43	366.81	260.29
To Paraguari																				
At Asuncion, total	138.32	114.85	113.77	91.40	121.79	98.31	97.24	74.86	116.28	92.80	91.73	69.35	141.63	118.14	117.08	94.71	96.43	72.96	71.89	49.52
Loading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Truck to Paraguari	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Paraguari, total $/mt	143.95	120.48	117.40	95.03	127.42	103.94	100.87	78.49	121.91	98.43	95.36	72.98	147.26	123.77	120.71	98.34	102.06	78.59	75.52	53.15
Paraguari, $/mt nutrient	319.89	267.73	260.89	211.18	277.00	225.96	219.28	170.63	203.18	164.05	158.93	121.63	-	-	-		486.00	374.24	359.62	253.10
To San Juan Bautista																				
At Asuncion, total	138.32	114.85	113.77	91.40	121.79	98.31	97.24	74.86	116.28	92.80	91.73	69.35	141.63	118.14	117.08	94.71	96.43	72.96	71.89	49.52
Loading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Truck to San Juan Bautista	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
San Juan Bautista, total $/mt	147.38	123.91	120.83	98.46	130.85	107.37	104.30	81.92	125.34	101.86	98.79	76.41	150.69	127.20	124.14	101.77	105.49	82.02	78.95	56.58
San Juan Bautista, $/mt nutrient	327.51	275.36	268.51	218.80	284.46	233.41	226.74	178.09	208.90	169.77	164.65	127.35	-	-	-		502.33	390.57	375.95	269.43
To Pedro Juan Caballero																				
At Asuncion, total	138.32	114.85	113.77	91.40	121.79	98.31	97.24	74.86	116.28	92.80	91.73	69.35	141.63	118.14	117.08	94.71	96.43	72.96	71.89	49.52
Loading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Truck to Pedro Juan Caballero	21.60	21.60	21.60	21.60	21.60	21.60	21.60	21.60	21.60	21.60	21.60	21.60	21.60	21.60	21.60	21.60	21.60	21.60	21.60	21.60
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Pedro Juan Caballero, total $/mt	163.92	140.45	137.37	115.00	147.39	123.91	120.84	98.46	141.88	118.40	115.33	92.95	167.23	143.74	140.68	118.31	122.03	98.56	95.49	73.12
Pedro Juan Caballero, $/mt nutrient	364.27	312.11	305.27	255.56	320.41	269.37	262.70	214.04	236.47	197.33	192.22	154.92	-	-	-		581.10	469.33	454.71	348.19
To Encarnacion																				
At Asuncion, total	138.32	114.85	113.77	91.40	121.79	98.31	97.24	74.86	116.28	92.80	91.73	69.35	141.63	118.14	117.08	94.71	96.43	72.96	71.89	49.52
Loading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Truck to Encarnacion	9.55	9.55	9.55	9.55	9.55	9.55	9.55	9.55	9.55	9.55	9.55	9.55	9.55	9.55	9.55	9.55	9.55	9.55	9.55	9.55
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Encarnacion, total $/mt	151.87	128.40	125.32	102.95	135.34	111.86	108.79	86.41	129.83	106.35	103.28	80.90	155.18	131.69	128.63	106.26	109.98	86.51	83.44	61.07
Encarnacion, $/mt nutrient	337.49	285.33	278.49	228.78	291.22	243.17	236.50	187.85	216.38	177.25	172.13	134.83	-	-			523.71	411.95	397.33	290.81
To San Pedro																				
At Asuncion, total	138.32	114.85	113.77	91.40	121.79	98.31	97.24	74.86	116.28	92.80	91.73	69.35	141.63	118.14	117.08	94.71	96.43	72.96	71.89	49.52
Loading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Truck to San Pedro	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
San Pedro, total $/mt	157.05	133.58	130.50	108.13	140.52	117.04	113.97	91.59	135.01	111.53	108.46	86.08	160.36	136.87	133.81	111.44	115.16	91.69	88.62	66.25
San Pedro, $/mt nutrient	349.00	296.84	290.00	240.29	305.48	254.43	247.76	199.11	225.02	185.88	180.77	143.47	-	-	-		548.38	436.62	422.00	315.48

[a] C.I.F. Value for tax purposes = (F.O.B. price + expenses) x 1.20; customs = 8.33% of C.I.F. Value for tax purpose.

Table A-11. Cost of Imported Fertilizers through Buenos Aires Via Truck to Paraguay through Asuncion

	Urea (45-0-0)				TSP (0-46-0)				KCl (0-0-60)				DAP (18-46-0)				$(NH_4)_2SO_4$ (21-0-0)			
	Bagged		Bulk		Bagged		Bulk		Bagged		Bulk		Bagged		Bulk		Bagged		Bulk	
	US	F	US	F	US	F	US	F	US	F	US	F	US	F	US	F	US	F	US	F
C.I.F. Buenos Aires	95.30	74.00	75.80	55.50	80.30	59.00	60.80	40.50	75.30	54.00	55.80	35.50	98.30	77.00	78.80	58.50	57.30	36.00	37.80	17.50
Ins. 0.2%	.19	.15	.15	.11	.16	.12	.12	.08	.15	.11	.11	.07	.20	.15	.16	.12	.11	.07	.08	.04
Port Expense, Buenos Aires	5.85	5.85	3.07	3.07	5.85	5.85	3.07	3.07	5.85	5.85	3.07	3.07	5.85	5.85	3.07	3.07	5.85	5.85	3.07	3.07
Truck to Asuncion	31.50	31.50	31.50	31.50	31.50	31.50	31.50	31.50	31.50	31.50	31.50	31.50	31.50	31.50	31.50	31.50	31.50	31.50	31.50	31.50
C.I.F. Asuncion	132.84	111.50	110.52	90.18	117.81	96.47	95.49	75.15	112.80	91.46	90.48	70.14	135.85	114.50	113.53	93.19	94.76	73.42	72.45	52.11
Customs, 8.33%[a]	13.28	11.15	11.05	9.01	11.78	9.64	9.54	7.51	11.28	9.14	9.04	7.01	13.58	11.45	11.35	9.31	9.47	7.34	7.24	5.21
Stamps & fees	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Asuncion, total $/mt	150.12	126.65	125.57	103.19	133.59	110.11	109.03	86.66	128.08	104.60	103.52	81.15	153.43	129.95	128.88	106.50	108.23	84.76	83.69	61.32
Asuncion, $/mt nutrient	333.60	281.44	279.04	229.31	290.41	239.37	237.02	188.39	213.47	174.33	172.53	135.25	–	–	–	–	515.38	403.62	398.52	292.00
To Cnel. Oviedo																				
At Asuncion, total	150.12	126.65	125.57	103.19	133.59	110.11	109.03	86.66	128.08	104.60	103.52	81.15	153.43	129.95	128.88	106.50	108.23	84.76	83.69	61.32
Truck to Cnel. Oviedo	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Cnel. Oviedo, total $/mt	155.26	131.79	129.71	107.33	138.73	115.25	113.17	90.80	133.22	109.74	107.66	85.29	158.57	135.09	133.02	110.64	113.37	89.90	87.83	65.46
Cnel. Oviedo, $/mt nutrient	345.02	292.87	288.24	238.51	301.59	250.54	246.02	197.39	222.03	182.90	179.43	142.15	–	–	–	–	539.86	428.10	418.24	311.71
To Paraguari																				
At Asuncion, total	150.12	126.65	125.57	103.19	133.59	110.11	109.03	86.66	128.08	104.60	103.52	81.15	153.43	129.95	128.88	106.50	108.23	84.76	83.69	61.32
Truck to Paraguari	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Paraguari, total $/mt	153.75	130.28	128.20	105.82	137.22	113.74	111.66	89.29	131.71	108.23	106.15	83.78	157.06	133.58	131.51	109.13	111.86	88.39	86.32	63.95
Paraguari, $/mt nutrient	341.67	289.51	284.89	235.16	298.30	247.26	242.74	194.11	219.52	180.38	176.92	139.63	–	–	–	–	532.67	420.90	411.05	304.52
To San Juan Bautista																				
At Asuncion, total	150.12	126.65	125.57	103.19	133.59	110.11	109.03	86.66	128.08	104.60	103.52	81.15	153.43	129.95	128.88	106.50	108.23	84.76	83.69	61.32
Truck to San Juan Bautista	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
San Juan Bautista, total $/mt	157.18	133.71	131.63	109.25	140.65	117.17	115.09	92.72	135.14	111.66	109.58	87.21	160.49	137.01	134.94	112.56	115.29	91.82	89.75	67.38
San Juan Bautista, $/mt nutrient	349.29	297.13	292.51	242.78	305.76	254.72	250.20	201.57	225.23	186.10	182.63	145.35	–	–	–	–	549.00	437.24	427.38	320.86
To Pedro Juan Caballero																				
At Asuncion, total	150.12	126.65	125.57	103.19	133.59	110.11	109.03	86.66	128.08	104.60	103.52	81.15	153.43	129.95	128.88	106.50	108.23	84.76	83.69	61.32
Truck to Pedro Juan Caballero	21.60	21.60	21.60	21.60	21.60	21.60	21.60	21.60	21.60	21.60	21.60	21.60	21.60	21.60	21.60	21.60	21.60	21.60	21.60	21.60
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Pedro Juan Caballero, total $/mt	173.72	150.25	148.17	125.79	157.19	133.71	131.63	109.26	151.68	128.20	126.12	103.75	177.03	153.55	151.48	129.10	131.83	108.36	106.29	83.92
Pedro Juan Caballero, $/mt nutrient	386.04	333.89	329.27	279.53	341.72	290.67	286.15	237.52	252.80	213.67	210.20	172.92	–	–	–	–	627.76	516.00	506.14	399.62
To Encarnacion																				
At Asuncion, total	150.12	126.65	125.57	103.19	133.59	110.11	109.03	86.66	128.08	104.60	103.52	81.15	153.43	129.95	128.88	106.50	108.23	84.76	83.69	61.32
Truck to Encarnacion	9.55	9.55	9.55	9.55	9.55	9.55	9.55	9.55	9.55	9.55	9.55	9.55	9.55	9.55	9.55	9.55	9.55	9.55	9.55	9.55
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Encarnacion, total $/mt	161.67	138.20	136.12	113.74	145.14	121.66	119.58	97.21	139.63	116.15	114.07	91.70	164.98	141.50	139.43	117.05	119.78	96.31	94.24	71.87
Encarnacion, $/mt nutrient	359.27	307.11	302.49	252.76	315.52	264.48	259.96	211.33	232.72	193.58	190.12	152.83	–	–	–	–	570.38	458.62	448.76	342.24
To San Pedro																				
At Asuncion, total	150.12	126.65	125.57	103.19	133.59	110.11	109.03	86.66	128.08	104.60	103.52	81.15	153.43	129.95	128.88	106.50	108.23	84.76	83.69	61.32
Truck to San Pedro	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
San Pedro, total $/mt	166.85	143.38	141.30	118.92	150.32	126.84	124.76	102.39	144.81	121.33	119.25	96.88	170.16	146.68	144.61	122.23	124.96	101.49	99.42	77.05
San Pedro, $/mt nutrient	370.78	318.62	314.00	264.27	326.78	275.74	271.22	222.59	241.35	202.22	198.75	161.47	–	–	–	–	595.05	483.29	473.43	366.90

[a]See footnote "a" table A-10.

Table A-12. Cost of Imported Fertilizers through Buenos Aires Via Rail to Paraguay through Encarnacion

	Urea (45-0-0)				TSP (0-46-0)				KCl (0-0-60)				DAP (18-46-0)				$(NH_4)_2SO_4$ (21-0-0)			
	Bagged		Bulk		Bagged		Bulk		Bagged		Bulk		Bagged		Bulk		Bagged		Bulk	
	US	F	US	F	US	F	US	F	US	F	US	F	US	F	US	F	US	F	US	F
C.I.F. Buenos Aires	95.30	74.00	75.80	55.50	80.30	59.00	60.80	40.50	75.30	54.00	55.80	35.50	98.30	77.00	78.80	58.50	57.30	36.00	37.80	17.50
Ins. 0.27	.19	.15	.15	.11	.16	.12	.12	.08	.15	.11	11	.07	.20	.15	.16	.12	.11	.07	.08	.04
Port expense, Buenos Aires	5.85	5.85	3.07	3.07	5.85	5.85	3.07	3.07	5.85	5.85	3.07	3.07	5.85	5.85	3.07	3.07	5.85	5.85	3.07	3.07
Rail to Encarnacion	7.65	7.65	7.65	7.65	7.65	7.65	7.65	7.65	7.65	7.65	7.65	7.65	7.65	7.65	7.65	7.65	7.65	7.65	7.65	7.65
C.I.F. Encarnacion	108.99	87.65	86.67	66.33	93.96	72.62	71.64	51.30	88.95	67.61	66.63	46.29	112.00	90.65	89.68	69.34	70.91	49.57	48.60	28.26
Customs, 8.337[a]	10.89	8.76	8.66	6.63	9.39	7.26	7.16	5.13	8.89	6.76	6.66	4.62	11.20	9.06	8.96	6.93	7.09	4.95	4.86	2.82
Stamps & fees	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Subtotal Encarnacion	123.88	100.41	99.33	76.96	107.35	83.88	82.80	60.43	101.84	78.37	77.29	54.91	127.20	103.71	102.64	80.27	82.00	58.52	57.46	35.08
To Cnel. Oviedo																				
Subtotal Encarnacion	123.88	100.41	99.33	76.96	107.35	83.88	82.80	60.43	101.84	78.37	77.29	54.91	127.20	103.71	102.64	80.27	82.00	58.52	57.46	35.08
Train to Villarrica	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09
Handling	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Truck to Cnel. Oviedo	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Cnel. Oviedo, total $/mt	131.05	107.58	104.50	82.13	114.52	91.05	87.97	65.60	109.01	85.54	82.46	60.08	134.37	110.88	107.81	85.44	89.17	65.69	62.63	40.25
Cnel. Oviedo, $/mt nutrient	291.22	239.07	232.22	182.51	248.96	197.93	191.24	142.61	181.68	142.57	137.43	100.13					424.62	312.81	298.24	191.67
To Paraguari																				
Subtotal Encarnacion	123.88	100.41	99.33	76.96	107.35	83.88	82.80	60.43	101.84	78.37	77.29	54.91	127.20	103.71	102.64	80.27	82.00	58.52	57.46	35.08
Train to Paraguari	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Paraguari, total $/mt	128.36	104.89	102.81	80.44	111.83	88.36	86.28	63.91	106.32	82.85	80.77	58.39	131.68	108.19	106.12	83.75	86.48	63.00	60.94	38.56
Paraguari, $/mt nutrient	285.24	233.09	228.47	178.76	243.11	192.09	187.57	138.93	177.20	138.08	134.62	97.32	–	–	–		411.81	300.00	290.19	183.62
To San Juan Bautista																				
Subtotal Encarnacion	123.88	100.41	99.33	76.96	107.35	83.88	82.80	60.43	101.84	78.37	77.29	54.91	127.20	103.71	102.64	80.27	82.00	58.52	57.46	35.08
Train to Cnel. Bogado	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50
Handling	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Truck to San Juan Bautista	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
San Juan Bautista, total $/mt	131.32	107.85	104.77	82.40	114.79	91.32	88.24	65.87	109.28	85.81	82.73	60.35	134.64	111.15	108.08	85.71	89.44	65.96	62.90	40.52
San Juan Bautista, $/mt nutrient	291.82	239.67	232.82	183.11	249.54	198.52	191.83	143.20	182.13	143.02	137.88	100.58	–	–	–		425.90	314.10	299.52	192.95
To Pedro Juan Caballero																				
Subtotal Encarnacion	123.88	100.41	99.33	76.96	107.35	83.88	82.80	60.43	101.84	78.37	77.29	54.91	127.20	103.71	102.64	80.27	82.00	58.52	57.46	35.08
Train to Villarrica	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09
Handling	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Truck to Pedro Juan Caballero	17.67	17.67	17.67	17.67	17.67	17.67	17.67	17.67	17.67	17.67	17.67	17.67	17.67	17.67	17.67	17.67	17.67	17.67	17.67	17.67
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Pedro Juan Caballero, total $/mt	147.64	124.17	121.09	98.72	131.11	107.67	104.56	82.19	125.60	102.13	99.05	76.67	150.96	127.47	124.40	102.03	105.76	82.28	79.22	56.84
Pedro Juan Caballero, $/mt nutrient	328.09	275.93	269.09	219.38	285.02	234.00	227.30	178.67	209.33	170.22	165.08	127.78	–	–			503.62	391.81	377.24	270.67
To Encarnacion																				
Subtotal Encarnacion	123.88	100.41	99.33	76.96	107.35	83.88	82.80	60.43	101.84	78.37	77.29	54.91	127.20	103.71	102.64	80.27	82.00	58.52	57.46	35.08
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Encarnacion, total $/mt	125.88	102.41	100.33	77.96	109.35	85.88	83.80	61.43	103.84	80.37	78.29	55.91	129.20	105.71	103.64	81.27	84.00	60.52	58.46	36.08
Encarnacion, $/mt nutrient	279.73	227.58	222.96	173.24	237.72	186.70	182.17	133.54	173.07	133.95	130.48	93.18	–		–		400.00	288.19	278.38	171.81
To San Pedro																				
Subtotal Encarnacion	123.88	100.41	99.33	76.96	107.35	83.88	82.80	60.43	101.84	78.37	77.29	54.91	127.20	103.71	102.64	80.27	82.00	58.52	57.46	35.08
Train to Villarrica	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09
Handling	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Truck to San Pedro	11.08	11.08	11.08	11.08	11.08	11.08	11.08	11.08	11.08	11.08	11.08	11.08	11.08	11.08	11.08	11.08	11.08	11.08	11.08	11.08
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
San Pedro, total $/mt	141.05	117.58	114.50	92.13	124.52	101.05	97.97	75.60	119.01	95.54	92.46	70.08	144.37	120.88	117.81	95.44	99.17	75.69	72.63	50.25
San Pedro, $/mt nutrient	313.44	261.29	254.44	204.73	279.70	219.67	212.98	164.35	198.35	159.23	154.10	116.80	–	–	–	–	472.24	360.43	345.86	239.29

[a]See footnote "a" table A-10.

Table A-13. Cost of Imported Fertilizers through Buenos Aires Via River to Paraguay through Encarnacion

	Urea (45-0-0)				TSP (0-46-0)				KCl (0-0-60)				DAP (18-46-0)				$(NH_4)_2SO_4$ (21-0-0)			
	Bagged		Bulk		Bagged		Bulk		Bagged		Bulk		Bagged		Bulk		Bagged		Bulk	
	US	F	US	F	US	F	US	F	US	F	US	F	US	F	US	F	US	F	US	F
C.I.F. Buenos Aires	95.30	74.00	75.80	55.50	80.30	59.00	60.80	40.50	75.30	54.00	55.80	35.50	98.30	77.00	78.80	58.50	57.30	36.00	37.80	17.50
Ins. 0.2%	.19	.15	.15	.11	.16	.12	.12	.08	.15	.11	.11	.07	.20	.15	.16	.12	.11	07	.08	.04
Port expense, Buenos Aires	5.85	5.85	3.07	3.07	5.85	5.85	3.07	3.07	5.85	5.85	3.07	3.07	5.85	5.85	3.07	3.07	5.85	5.85	3.07	3.07
River to Encarnacion	14.33	14.33	14.33	14.33	14.33	14.33	14.33	14.33	14.33	14.33	14.33	14.33	14.33	14.33	14.33	14.33	14.33	14.33	14.33	14.33
River exchange (handling)	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
C.I.F. Encarnacion	117.67	96.33	94.35	74.01	102.64	81.30	79.32	58.98	97.63	76.29	74.31	53.97	120.68	99.33	97.36	77.02	79.59	58.25	56.28	35.94
Customs, 8.33%[a]	11.76	9.63	9.43	7.40	10.26	8.13	7.93	5.89	9.76	7.62	7.43	5.39	12.06	9.93	9.73	7.70	7.95	5.82	5.62	3.59
Stamps & fees	4.00	4.00	.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Handling at customs	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13
Encarnacion, total $/mt	137.56	114.09	111.91	89.54	121.03	97.56	95.38	73.00	115.52	92.04	89.87	67.49	140.87	117.39	115.22	92.85	95.67	72.20	70.03	47.66
To Cnel. Oviedo																				
Subtotal Encarnacion	137.56	114.09	111.91	89.54	121.03	97.56	95.38	73.00	115.52	92.04	89.87	67.49	140.87	117.39	115.22	92.85	95.67	72.20	70.03	47.66
Truck to Cnel. Oviedo	10.58	10.58	10.58	10.58	10.58	10.58	10.58	10.58	10.58	10.58	10.58	10.58	10.58	10.58	10.58	10.58	10.58	10.58	10.58	10.58
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Cnel. Oviedo, total $/mt	150.14	126.67	123.49	101.12	133.61	110.14	106.96	84.58	128.10	104.62	101.45	79.07	153.45	129.97	126.80	104.43	108.25	84.78	81.61	59.24
Cnel. Oviedo, $/mt nutrient	333.64	281.49	274.42	224.71	290.46	239.43	232.52	183.87	213.50	174.37	169.08	131.78	-	-	-	-	515.48	403.71	388.62	282.10
To Paraguari																				
Subtotal Encarnacion	137.56	114.09	111.91	89.54	121.03	97.56	95.38	73.00	115.52	92.04	89.87	67.49	140.87	117.39	115.22	92.85	95.67	72.20	70.03	47.66
Truck to Paraguari	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Paraguari, total $/mt	147.48	124.01	120.83	98.46	130.95	107.48	104.30	81.92	125.44	101.96	98.79	76.41	150.79	127.31	124.14	101.77	105.59	82.12	78.95	56.58
Paraguari, $/mt nutrient	327.73	275.58	268.51	218.80	284.67	233.65	226.74	178.09	209.07	169.93	164.65	127.35	-	–	–	-	592.81	391.05	375.95	269.43
To San Juan Bautista																				
Subtotal Encarnacion	137.56	114.09	111.91	89.54	121.03	97.56	95.38	73.00	115.52	92.04	89.87	67.49	140.87	117.39	115.22	92.85	95.67	72.20	70.03	47.66
Truck to San Juan Bautista	4.49	4.49	4.49	4.49	4.49	4.49	4.49	4.49	4.49	4.49	4.49	4.49	4.49	4.49	4.49	4.49	4.49	4.49	4.49	4.49
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
San Juan Bautista, total $/mt	144.05	120.58	117.40	95.03	127.52	104.05	100.87	78.49	122.01	98.53	95.36	72.98	147.36	123.88	120.71	98.34	102.16	78.69	75.52	53.15
San Juan Bautista, $/mt nutrient	320.11	267.96	260.89	211.18	277.22	226.20	219.28	170.63	203.35	164.22	158.93	121.63	–	–	–	–	486.48	374.71	359.62	253.10
To Pedro Juan Caballero																				
Subtotal Encarnacion	137.56	114.09	111.91	89.54	121.03	97.56	95.38	73.00	115.52	92.04	89.87	67.49	140.87	117.39	115.22	92.85	95.67	72.20	70.03	47.66
Truck to Pedro Juan Caballero	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Pedro Juan Caballero, total $/mt	166.14	142.67	139.49	117.12	149.61	126.14	122.96	100.58	144.10	120.62	117.45	95.07	169.45	145.97	142.80	120.43	124.25	100.78	97.61	75.24
Pedro Juan Caballero, $/mt nutrient	369.20	317.04	309.98	260.27	325.24	274.22	267.30	218.65	240.17	201.03	195.75	158.45	–	–	–	-	591.67	479.90	464.81	358.29
To Encarnacion																				
Subtotal Encarnacion	137.56	114.09	111.91	89.54	121.03	97.56	95.38	73.00	115.52	92.04	89.87	67.49	140.87	117.39	115.22	92.85	95.67	72.20	70.03	47.66
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Encarnacion, total $/mt	139.56	116.09	112.91	90.54	123.03	99.56	96.38	74.00	117.52	94.04	90.87	68.49	142.87	119.39	116.22	93.85	97.67	74.20	71.03	38.66
Encarnacion, $/mt nutrient	310.13	257.98	250.91	201.20	267.46	216.43	209.52	160.87	195.87	156.73	151.45	114.15	-	–	–	-	465.10	353.33	338.24	231.71
To San Pedro																				
Subtotal Encarnacion	137.56	114.09	111.91	89.54	121.03	97.56	95.38	73.00	115.52	92.04	89.87	67.49	140.87	117.39	115.22	92.85	95.67	72.20	70.03	47.66
Truck to San Pedro	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
San Pedro, total $/mt	159.56	136.09	132.91	110.54	143.03	119.56	116.38	94.00	137.52	114.04	110.87	88.49	162.87	139.39	136.22	113.85	117.67	94.20	91.03	68.66
San Pedro, $/mt nutrient	354.58	302.42	295.36	245.64	310.93	259.91	253.00	204.35	229.20	190.07	184.78	147.48	-	–	-	-	560.33	448.57	433.48	326.95

[a]See footnote "a" table A-10.

Table A-14. Cost of Imported Fertilizers through Paranagua Via Truck to Paraguay through Pto. Pte. Stroessner

	Urea (45-0-0)				TSP (0-46-0)				KCl (0-0-60)				DAP (18-46-0)				$(NH_4)_2SO_4$ (21-0-0)			
	Bagged		Bulk		Bagged		Bulk		Bagged		Bulk		Bagged		Bulk		Bagged		Bulk	
	US	F	US	F	US	F	US	F	US	F	US	F	US	F	US	F	US	F	US	F
F.O.B. Gulf Coast	65.00	65.00	47.00	47.00	50.00	50.00	32.00	32.00	45.00	45.00	27.00	27.00	68.00	68.00	50.00	50.00	27.00	27.00	9.00	9.00
Ocean freight	26.00	8.50	24.50	8.00	26.00	8.50	24.50	8.00	26.00	8.50	24.50	8.00	26.00	8.50	24.50	8.00	26.00	8.50	24.50	8.00
C.I.F. Paranagua	91.00	73.50	71.50	55.00	76.00	58.50	56.50	40.00	71.00	53.50	51.50	35.00	94.00	76.50	74.50	58.00	53.00	35.50	33.50	17.00
Ins. 0.2%	.18	.15	.14	.11	.15	.12	.11	.08	.14	.11	.10	.07	.19	.15	.15	.12	.11	.07	.07	.03
Port expense, Paranagua	12.98	12.98	10.03	10.03	12.98	12.98	10.03	10.03	12.98	12.98	10.03	10.03	12.98	12.98	10.03	10.03	12.98	12.98	10.03	10.03
Loading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Subtotal Paranagua	106.16	88.63	82.67	66.14	91.13	73.60	67.64	51.11	86.12	68.59	62.63	46.10	109.17	91.63	85.68	69.15	68.09	50.55	44.60	28.06
Truck to Pte. Pto. Stroessner	11.18	11.18	11.18	11.18	11.18	11.18	11.18	11.18	11.18	11.18	11.18	11.18	11.18	11.18	11.18	11.18	11.18	11.18	11.18	11.18
Subtotal Pte. Pto. Stroessner	117.34	99.81	93.85	77.32	102.31	84.78	78.82	62.29	97.30	79.77	73.81	57.28	120.35	102.81	96.86	80.33	79.27	61.73	55.78	39.24
Customs, 8.33%[a]	11.73	9.98	9.38	7.73	10.23	8.47	7.88	6.22	9.73	7.97	7.38	5.73	12.03	10.28	9.68	8.03	7.92	6.17	5.57	3.92
Stamps & fees	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Pte. Pto. Stroessner, total $/mt	133.07	113.79	107.23	89.05	116.54	97.25	90.70	72.51	111.03	91.74	85.19	67.01	136.38	117.09	110.54	92.36	91.19	71.90	65.35	47.16
To Cnel. Oviedo																				
Pte. Pto. Stroessner, total	133.07	113.79	107.23	89.05	116.54	97.25	90.70	72.51	111.03	91.74	85.19	67.01	136.38	117.09	110.54	92.36	91.19	71.90	65.35	47.16
Truck to Cnel. Oviedo	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Cnel. Oviedo, total $/mt	140.15	120.87	113.31	95.13	123.62	104.33	96.78	78.59	118.11	98.82	91.27	73.09	143.46	124.17	116.62	98.44	98.27	78.98	71.43	53.24
Cnel. Oviedo, $/mt nutrient	311.44	268.60	251.80	211.40	268.74	226.80	210.39	170.85	196.85	164.70	152.12	121.82	–	–	–	–	467.95	376.10	340.14	253.52
To Paraguari																				
Pte. Pto. Stroessner, total	133.07	113.79	107.23	89.05	116.54	97.25	90.70	72.51	111.03	91.74	85.19	67.01	136.38	117.09	110.54	92.36	91.19	71.90	65.35	47.16
Truck to Paraguari	7.64	7.64	7.64	7.64	7.64	7.64	7.64	7.64	7.64	7.64	7.64	7.64	7.64	7.64	7.64	7.64	7.64	7.64	7.64	7.64
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Paraguari, total $/mt	142.71	123.43	115.87	97.69	126.18	106.89	99.34	81.15	120.67	101.38	93.83	75.65	146.02	126.73	119.18	101.00	100.83	81.54	73.99	55.80
Paraguari, $/mt nutrient	317.13	274.29	257.49	217.09	274.30	232.37	215.96	176.41	201.12	168.97	156.38	126.08	–	–	–	–	480.14	388.29	352.33	265.71
To San Juan Bautista																				
Pte. Pto. Stroessner, total	133.07	113.79	107.23	89.05	116.54	97.25	90.70	72.51	111.03	91.74	85.19	67.01	136.38	117.09	110.54	92.36	91.19	71.90	65.35	47.16
Truck to San Juan Bautista	11.07	11.07	11.07	11.07	11.07	11.07	11.07	11.07	11.07	11.07	11.07	11.07	11.07	11.07	11.07	11.07	11.07	11.07	11.07	11.07
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
San Juan Bautista, total $/mt	146.14	126.86	119.30	101.12	129.61	110.32	102.77	84.58	124.10	104.81	97.26	79.08	149.45	130.16	122.61	104.43	104.26	84.97	77.42	59.23
San Juan Bautista, $/mt nutrient	324.76	281.91	265.11	224.71	281.76	239.83	223.41	183.87	206.83	174.68	162.10	131.80	–	–	–	–	496.48	404.62	368.67	282.05
To Pedro Juan Caballero																				
Pte. Pto. Stroessner, total	133.07	113.79	107.23	89.05	116.54	97.25	90.70	72.51	111.03	91.74	85.19	67.01	136.38	117.09	110.54	92.36	91.19	71.90	65.35	47.16
Truck to Pedro Juan Caballero	21.07	21.07	21.07	21.07	21.07	21.07	21.07	21.07	21.07	21.07	21.07	21.07	21.07	21.07	21.07	21.07	21.07	21.07	21.07	21.07
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Pedro Juan Caballero, total $/mt	156.14	136.86	129.30	111.12	139.61	120.32	112.77	94.58	134.10	114.81	107.26	89.08	159.45	140.16	132.61	114.43	114.26	94.97	87.42	69.23
Pedro Juan Caballero, $/mt nutrient	346.98	304.13	287.33	246.93	303.50	261.57	245.15	205.61	223.50	191.35	178.77	148.47	–	–	–	–	544.10	452.24	416.29	329.67
To Encarnacion																				
Pte. Pto. Stroessner, total	133.07	113.79	107.23	89.05	116.54	97.25	90.70	72.51	111.03	91.74	85.19	67.01	136.38	117.09	110.54	92.36	91.19	71.90	65.35	47.16
Truck to Encarnacion	15.56	15.56	15.56	15.56	15.56	15.56	15.56	15.56	15.56	15.56	15.56	15.56	15.56	15.56	15.56	15.56	15.56	15.56	15.56	15.56
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Encarnacion, total $/mt	150.63	131.35	123.79	105.61	134.10	114.81	107.26	89.07	128.59	109.30	101.75	83.57	153.94	134.65	127.10	108.92	108.75	89.46	81.91	63.72
Encarnacion, $/mt nutrient	334.73	291.89	275.09	234.69	291.52	249.59	233.17	193.63	214.32	182.17	169.58	139.28	–	–	–	–	517.86	426.00	390.05	303.43
To San Pedro																				
Pte. Pto. Stroessner, total	133.07	113.79	107.23	89.05	116.54	97.25	90.70	72.51	111.03	91.74	85.19	67.01	136.38	117.09	110.54	92.36	91.19	71.90	65.35	47.16
Truck to San Pedro	14.49	14.49	14.49	14.49	14.49	14.49	14.49	14.49	14.49	14.49	14.49	14.49	14.49	14.49	14.49	14.49	14.49	14.49	14.49	14.49
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
San Pedro, total $/mt	149.56	130.28	122.72	104.54	133.03	113.74	106.19	88.00	127.52	108.23	100.68	82.50	152.87	133.58	126.03	107.85	107.68	88.39	80.84	62.65
San Pedro, $/mt nutrient	332.36	289.51	272.71	232.31	289.20	247.26	230.85	191.30	212.53	180.38	167.80	137.50	–	–	–	–	512.76	420.90	384.95	298.33

[a]See footnote "a" table A-10.

Table A-15. Cost of Imported Fertilizers through Paranagua Via Truck to Paraguay through Pedro Juan Caballero

	Urea (45-0-0)				TSP (0-46-0)				KCl (0-0-60)				DAP (18-46-0)				$(NH_4)_2SO_4$ (21-0-0)			
	Bagged		Bulk		Bagged		Bulk		Bagged		Bulk		Bagged		Bulk		Bagged		Bulk	
	US	F	US	F	US	F	US	F	US	F	US	F	US	F	US	F	US	F	US	F
Subtotal Paranagua	106.16	88.63	82.67	66.14	91.13	73.60	67.64	51.11	86.12	68.59	62.63	46.10	109.17	91.63	85.68	69.15	68.09	50.55	44.60	28.06
Truck to Pedro Juan Caballero	23.31	23.31	23.31	23.31	23.31	23.31	23.31	23.31	23.31	23.31	23.31	23.31	23.31	23.31	23.31	23.31	23.31	23.31	23.31	23.31
Subtotal Pedro Juan Caballero	129.47	111.94	105.98	89.45	114.44	96.91	90.95	74.42	109.43	91.90	85.94	69.41	132.48	114.94	108.99	92.46	91.40	73.86	67.91	51.37
Customs, 8.33%[a]	12.94	11.19	10.59	8.94	11.44	9.69	9.09	7.44	10.94	9.19	8.59	6.94	13.24	11.49	10.89	9.24	9.14	7.38	6.79	5.13
Stamps & fees	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Subtotal Pedro Juan Caballero	146.41	127.13	120.57	102.39	129.88	110.60	104.04	85.86	124.37	105.09	98.53	80.35	149.72	130.43	123.88	105.70	104.54	85.24	78.70	60.50
To Cnel. Oviedo																				
Subtotal Pedro Juan Caballero	146.41	127.13	120.57	102.39	129.88	110.60	104.04	85.86	124.37	105.09	98.53	80.35	149.72	130.43	123.88	105.70	104.54	85.24	78.70	60.50
Truck to Cnel. Oviedo	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Cnel. Oviedo, total $/mt	164.41	145.13	137.57	119.39	147.88	128.60	121.04	102.86	142.37	123.09	115.53	97.35	167.72	148.43	140.88	122.70	122.54	103.24	95.70	77.50
Cnel. Oviedo, $/mt nutrient	365.36	322.51	305.71	265.31	321.48	279.57	263.13	223.61	237.28	205.15	192.55	162.25	–	–	–	–	583.52	491.62	455.71	369.05
To Paraguari																				
Subtotal Pedro Juan Caballero	146.41	127.13	120.57	102.39	129.88	110.60	104.04	85.86	124.37	105.09	98.53	80.35	149.72	130.43	123.88	105.70	104.54	85.24	78.70	60.50
Truck to Paraguari	20.09	20.09	20.09	20.09	20.09	20.09	20.09	20.09	20.09	20.09	20.09	20.09	20.09	20.09	20.09	20.09	20.09	20.09	20.09	20.09
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Paraguari, total $/mt	168.50	149.22	141.66	123.48	151.97	132.69	125.13	106.95	146.46	127.18	119.62	101.44	171.81	152.52	144.97	126.79	126.63	107.33	99.79	81.59
Paraguari, $/mt nutrient	374.44	331.60	314.80	274.40	330.37	288.46	272.02	232.50	244.10	211.97	199.37	169.07	–	–	–	–	603.00	511.10	475.19	388.52
To San Juan Bautista																				
Subtotal Pedro Juan Caballero	146.41	127.13	120.57	102.39	129.88	110.60	104.04	85.86	124.37	105.09	98.53	80.35	149.72	130.43	123.88	105.70	104.54	85.24	78.70	60.50
Truck to San Juan Bautista	22.09	22.09	22.09	22.09	22.09	22.09	22.09	22.09	22.09	22.09	22.09	22.09	22.09	22.09	22.09	22.09	22.09	22.09	22.09	22.09
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
San Juan Bautista, total $/mt	170.50	151.22	143.66	125.48	153.97	134.69	127.13	108.95	148.46	129.18	121.62	103.44	173.81	154.52	146.97	128.79	128.63	109.33	101.79	83.59
San Juan Bautista, $/mt nutrient	378.89	336.04	319.24	278.84	334.72	292.80	276.37	236.85	247.43	215.30	202.70	172.40	–	–	–	–	612.52	520.62	484.71	398.05
To Pedro Juan Caballero																				
Subtotal Pedro Juan Caballero	146.41	127.13	120.57	102.39	129.88	110.60	104.04	85.86	124.37	105.09	98.53	80.35	149.72	130.43	123.88	105.70	104.54	85.24	78.70	60.50
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Pedro Juan Caballero, total $/mt	148.41	129.13	121.57	103.39	131.88	112.60	105.04	86.86	126.37	107.09	99.53	81.35	151.72	132.43	124.88	106.70	106.54	87.24	79.70	61.50
Pedro Juan Caballero, $/mt nutrient	329.80	286.96	270.16	229.76	286.70	244.78	228.35	188.83	210.62	178.48	165.88	135.58	–	–	–	–	507.33	415.43	379.52	292.86
To Encarnacion																				
Subtotal Pedro Juan Caballero	146.41	127.13	120.57	102.39	129.88	110.60	104.04	85.86	124.37	105.09	98.53	80.35	149.72	130.43	123.88	105.70	104.54	85.24	78.70	60.50
Truck to Encarnacion	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Encarnacion, total $/mt	174.99	155.71	148.15	129.97	158.46	139.18	131.62	113.44	152.95	133.67	126.11	107.93	178.30	159.01	151.46	133.28	133.12	113.82	106.28	88.08
Encarnacion, $/mt nutrient	388.87	346.02	329.22	288.82	344.48	302.57	286.13	246.61	254.92	222.78	210.18	179.88	–	–	–	–	633.90	542.00	506.10	419.43
To San Pedro																				
Subtotal Pedro Juan Caballero	146.41	127.13	120.57	102.39	129.88	110.60	104.04	85.86	124.37	105.09	98.53	80.35	149.72	130.43	123.88	105.70	104.54	85.24	78.70	60.50
Truck to San Pedro	9.85	9.85	9.85	9.85	9.85	9.85	9.85	9.85	9.85	9.85	9.85	9.85	9.85	9.85	9.85	9.85	9.85	9.85	9.85	9.85
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
San Pedro, total $/mt	158.26	138.98	131.42	113.24	141.73	122.45	114.89	96.71	136.22	116.94	109.38	91.20	161.57	142.28	134.73	116.55	116.39	97.09	89.55	71.35
San Pedro, $/mt nutrient	351.69	308.84	292.04	251.64	308.11	266.20	249.76	210.24	227.03	194.90	182.30	152.00	–	–	–	–	554.24	462.33	426.43	339.76

[a]See footnote "a" table A-10.

Table A-16. Cost of Imported Fertilizers through Paranagua Via Train to Paraguay through Pedro Juan Caballero

	Urea (45-0-0)				TSP (0-46-0)				KCl (0-0-60)				DAP (18-46-0)				$(NH_4)_2SO_4$ (21-0-0)			
	Bagged		Bulk		Bagged		Bulk		Bagged		Bulk		Bagged		Bulk		Bagged		Bulk	
	US	F	US	F	US	F	US	F	US	F	US	F	US	F	US	F	US	F	US	F
Subtotal Paranagua	106.16	88.63	82.67	66.14	91.13	73.60	67.64	51.11	86.12	68.59	62.63	46.10	109.17	91.63	85.68	69.15	68.09	50.55	44.60	28.06
Train to Pedro Juan Caballero	20.55	20.55	20.55	20.55	20.55	20.55	20.55	20.55	20.55	20.55	20.55	20.55	20.55	20.55	20.55	20.55	20.55	20.55	20.55	20.55
Subtotal Pedro Juan Caballero	126.71	109.18	103.22	86.69	111.68	94.15	88.19	71.66	106.67	89.14	83.18	66.65	129.72	112.18	106.23	89.70	88.64	71.10	65.15	48.61
Customs, 8.33%[a]	12.67	10.91	10.32	8.66	11.16	9.41	8.81	7.16	10.66	8.91	8.31	6.66	12.97	11.21	10.62	8.97	8.86	7.11	6.51	4.86
Stamps & fees	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Subtotal Pedro Juan Caballero	143.38	124.09	117.54	99.35	126.84	107.56	101.00	82.82	121.33	102.05	95.49	77.31	146.69	127.39	120.85	102.67	101.50	82.21	75.66	57.47
Handling	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Subtotal Pedro Juan Caballero	145.38	124.09	118.54	100.35	128.84	109.56	102.00	83.82	123.33	104.05	96.49	78.31	148.69	129.39	121.85	103.67	103.50	84.21	76.66	58.47
To Cnel. Oviedo																				
Subtotal Pedro Juan Caballero	145.38	124.09	118.54	100.35	128.84	109.56	102.00	83.82	123.33	104.05	96.49	78.31	148.69	129.39	121.85	103.67	103.50	84.21	76.66	58.47
Truck to Cnel. Oviedo	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Cnel. Oviedo, total $/mt	163.38	142.09	135.54	117.35	146.84	127.56	119.00	100.82	141.33	122.05	113.49	95.31	166.69	147.39	138.85	120.67	121.50	102.21	93.66	75.47
Cnel. Oviedo, $/mt nutrient	363.07	315.76	301.20	260.78	319.22	277.30	258.70	219.17	235.55	203.42	189.15	158.85	–	–	-	-	578.57	486.71	446.00	359.38
To Paraguari																				
Subtotal Pedro Juan Caballero	145.38	124.09	118.54	100.35	128.84	109.56	102.00	83.82	123.33	104.05	96.49	78.31	148.69	129.39	121.85	103.67	103.50	84.21	76.66	58.47
Truck to Paraguari	20.09	20.09	20.09	20.09	20.09	20.09	20.09	20.09	20.09	20.09	20.09	20.09	20.09	20.09	20.09	20.09	20.09	20.09	20.09	20.09
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Paraguari, total $/mt	167.47	146.18	139.63	121.44	150.93	131.65	123.09	104.91	145.42	126.14	117.58	99.40	170.78	151.48	142.94	124.76	125.59	106.30	97.75	79.56
Paraguari, $/mt nutrient	372.16	324.84	310.29	269.87	328.11	286.20	267.59	228.07	242.37	210.23	195.97	165.67	–	–	-	-	598.05	506.19	465.48	378.86
To San Juan Bautista																				
Subtotal Pedro Juan Caballero	145.38	124.09	118.54	100.35	128.84	109.56	102.00	83.82	123.33	104.05	96.49	78.31	148.69	129.39	121.85	103.67	103.50	84.21	76.66	58.47
Truck to San Juan Bautista	22.09	22.09	22.09	22.09	22.09	22.09	22.09	22.09	22.09	22.09	22.09	22.09	22.09	22.09	22.09	22.09	22.09	22.09	22.09	22.09
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
San Juan Bautista, total $/mt	169.47	148.18	141.63	123.44	152.93	133.65	125.09	106.91	147.42	128.14	119.58	101.40	172.78	153.48	144.94	126.76	127.59	108.30	99.75	81.56
San Juan Bautista, $/mt nutrient	376.60	329.29	314.73	274.31	332.46	290.54	271.93	232.41	245.70	213.57	199.30	169.00	–	–	-	–	607.57	515.71	475.00	388.38
To Pedro Juan Caballero																				
Subtotal Pedro Juan Caballero	145.38	124.09	118.54	100.35	128.84	109.56	102.00	83.82	123.33	104.05	96.49	78.31	148.69	129.39	121.85	103.67	103.50	84.21	76.66	58.47
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Pedro Juan Caballero, total $/mt	147.38	126.09	119.54	101.35	130.84	111.56	103.00	84.82	125.33	106.05	97.49	79.31	150.69	131.39	122.85	104.67	105.50	86.21	77.66	59.47
Pedro Juan Caballero, $/mt nutrient	327.51	280.20	265.64	225.22	284.43	242.52	223.91	184.39	208.88	176.75	162.48	132.18	–	–	–	–	502.38	410.52	369.81	283.19
To Encarnacion																				
Subtotal Pedro Juan Caballero	145.38	124.09	118.54	100.35	128.84	109.56	102.00	83.82	123.33	104.05	96.49	78.31	148.69	129.39	121.85	103.67	103.50	84.21	76.66	58.47
Truck to Encarnacion	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58	26.58
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
Encarnacion, total $/mt	173.96	152.67	146.12	127.93	157.42	138.14	129.58	111.40	151.91	132.63	124.07	105.89	177.27	157.97	149.43	131.25	132.08	112.79	104.24	86.05
Encarnacion, $/mt nutrient	386.58	339.27	324.71	284.29	342.22	300.30	281.70	242.17	253.18	221.05	206.78	176.48	–	–	-	-	629.85	537.10	496.38	409.76
To San Pedro																				
Subtotal Pedro Juan Caballero	145.38	124.09	118.54	100.35	128.84	109.56	102.00	83.82	123.33	104.05	96.49	78.31	148.69	129.39	121.85	103.67	103.50	84.21	76.66	58.47
Truck to San Pedro	9.85	9.85	9.85	9.85	9.85	9.85	9.85	9.85	9.85	9.85	9.85	9.85	9.85	9.85	9.85	9.85	9.85	9.85	9.85	9.85
Unloading	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00
San Pedro, total $/mt	157.23	135.94	129.39	111.20	140.69	121.41	112.85	94.67	135.18	115.90	107.34	89.16	160.54	141.24	132.70	114.52	115.35	96.06	87.51	69.32
San Pedro, $/mt nutrient	349.40	302.09	287.53	247.11	305.85	263.93	245.33	205.80	225.30	193.17	178.90	148.60	–	-		–	549.29	457.43	416.71	330.10

[a]See footnote "a" table A-10.

Table A-17. Consumption of Fertilizer Materials in Paraguay 1960-1966 (13)

Fertilizer material	1960	1961	1962	1963	1964	1965	1966
				mt			
Ammonium sulfate, 21% N	35	113	54	67	30	35	5
Urea, 46% N	–	15	45	5	62	30	55
Ammonium nitrate, 33.5% N	–	–	50	–	–	–	–
Ammonium nitrosulfate, 26% N	1	2	4	5	–	5	–
Calcium ammonium nitrate, 20% N	1	31	52	28	40	50	–
Ca-Mg nitrate, 20.5% N 6% Mg	–	30	80	90	70	–	–
Renania phosphate, 26% P_2O_5	–	–	–	–	–	20	15
Thomas slag, 15.9% P_2O_5	–	–	50	–	11	–	–
Potassium sulfate, 30-50% K_2O	20	–	10	2	75	10	3
Potassium chloride, 60% K_2O	10	–	5	3	2	5	–
Triple superphosphate, 47-48% P_2O_5	5	1.5	30	–	–	–	–
Magnesium sulfate	–	–	–	8	10	30	37
Zinc sulfate	–	–	–	1.5	1	12	12
Others	10	–	5	1.5	11	1.5	5
Total	82	192.5	385	211	312	198.5	127.5

Table A-18. Consumption of Fertilizer Mixed Goods in Paraguay 1960-1966 (13)

Fertilizer grade	1960	1961	1962	1963	1964	1965	1966
				mt			
6-12-18	5	5	5	–	–	–	–
10-5-20-1	–	–	–	–	5	–	–
10-20-20	–	–	–	–	10	–	–
12-12-17-2	43	71	81	96	142.5	180	220
12-12-20	–	3	9	45	20	15	30
12-12-20-2	–	2.5	–	5	–	–	–
12-12-21	7	2	–	–	–	–	–
12-24-8	–	–	5	–	50	–	–
12-24-12	–	–	–	24	–	–	15
0-13-13	–	–	–	–	5	5	–
13-13-20	8	12.5	25	10	130	15	40
13-13-21	2	18.5	113	210	225	35	30
13-13-21-2	–	–	–	115	200	250	165
14-14-14	–	–	5	10	140	10	35
15-15-15	7	13	63	200	125	110	70
15-15-6-4	–	–	–	–	5	5	–
20-0-20	2	42.5	48	55	50	–	3
20-10-10	–	–	–	–	5	–	–
Total	74	170	354	770	1,112.5	575	608

Table A-19. Consumption of Fertilizers by Region 1965-1967 (13)

Department	1965	1966	1967
Capital	32	25	28
Concepcion	28	22	25
San Pedro	60	46	553
Cordillera	100	76	88
Guaira	93	70	81
Caaguazu	96	73	85
Caazapa	83	63	73
Itapua	75	57	366
Misiones	51	38	44
Paraguari	260	197	229
Alto Parana	12	9	11
Central	257	196	226
Neembucu	44	34	39
Amambay	19	14	516
Presidente Hayes	11	8	10
Boqueron	12	9	511
Total	1,233	937	2,885

Table A-20. New Laboratory Equipment and Supplies Needed by the Departmento de Suelos, Facultad de Agromia y Veterinaria

I. Instruments
- Perkin Elmer 290 B atomic absorption unit, complete with lamps for Ca, Mg, Zn, Mn, Cu, Fe.
- Coleman Jr. Colorimeter Model 6-C
- Zeromatic pH meter

II. General Laboratory Equipment
- Distiller unit for high capacity supply of distilled water
- Current stabilizer with adjustable output voltage to correct for current changes.
- Vacuum-pressure pumps with reserve tanks
- In-line water pump to increase pressure for automatic tray washer.
- 5 Hamilton Beech stirrer-units for texture analysis

III. Laboratory Supplies
- Plastic jugs and containers—8 to 25 liters
- New distilled water line with shut-off valves
- Pressure and vacuum lines to center lab bench with shut-off valves
- Paper towels and dispenser

IV. Soils Office Needs
- Metal file cabinet
- Desk calculator

Other supplies and reagents not available locally
- Replacement electrodes for Fisher 210 Accumet pH meter
- New burner unit for Hitachi Perkin Elmer FPF-2 flame photometer
- Reagents:
  - superfloc 127
  - antimony potassium tartrate (3 small battles)
  - ascorbic acid (10 small bottles)
  - phenol crystals (5 large bottles)
  - hydrogen peroxide (5 containers)
  - KCl, reagent grade (10 g)
  - $NaHCO_3$ (10 kg)

Locally available supplies and printed materials
- 10,000 soil sample boxes
- 1,000 shipping boxes
- Pamphlets on how to take soil samples
- Lab control sheets
- Report forms
- 10,000 plastic bags for sample box liners
- 1,000 plastic bags for research work, medium size

NOTATIONS

SEDIMENTARY

SILURIAN
TRIASSIC
QUATERNARY
ALLUVIUM

IGNEOUS ROCKS

THERALITE-TESCHENITE
LEUCITE BASALT, SODALITE, ANALCIMITE, LEUCITITE, LIMBURGITE
ESSEXITE-SHONKINITE
PHONOLITE-TINGUAITE
DIABASE, LAMPROPHYRE, MICROSIENITE

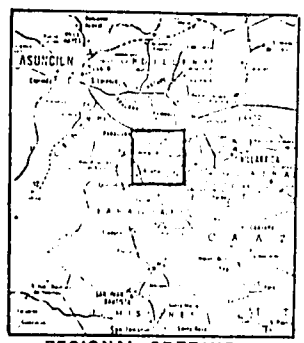
STRUCTURE ELEMENTS

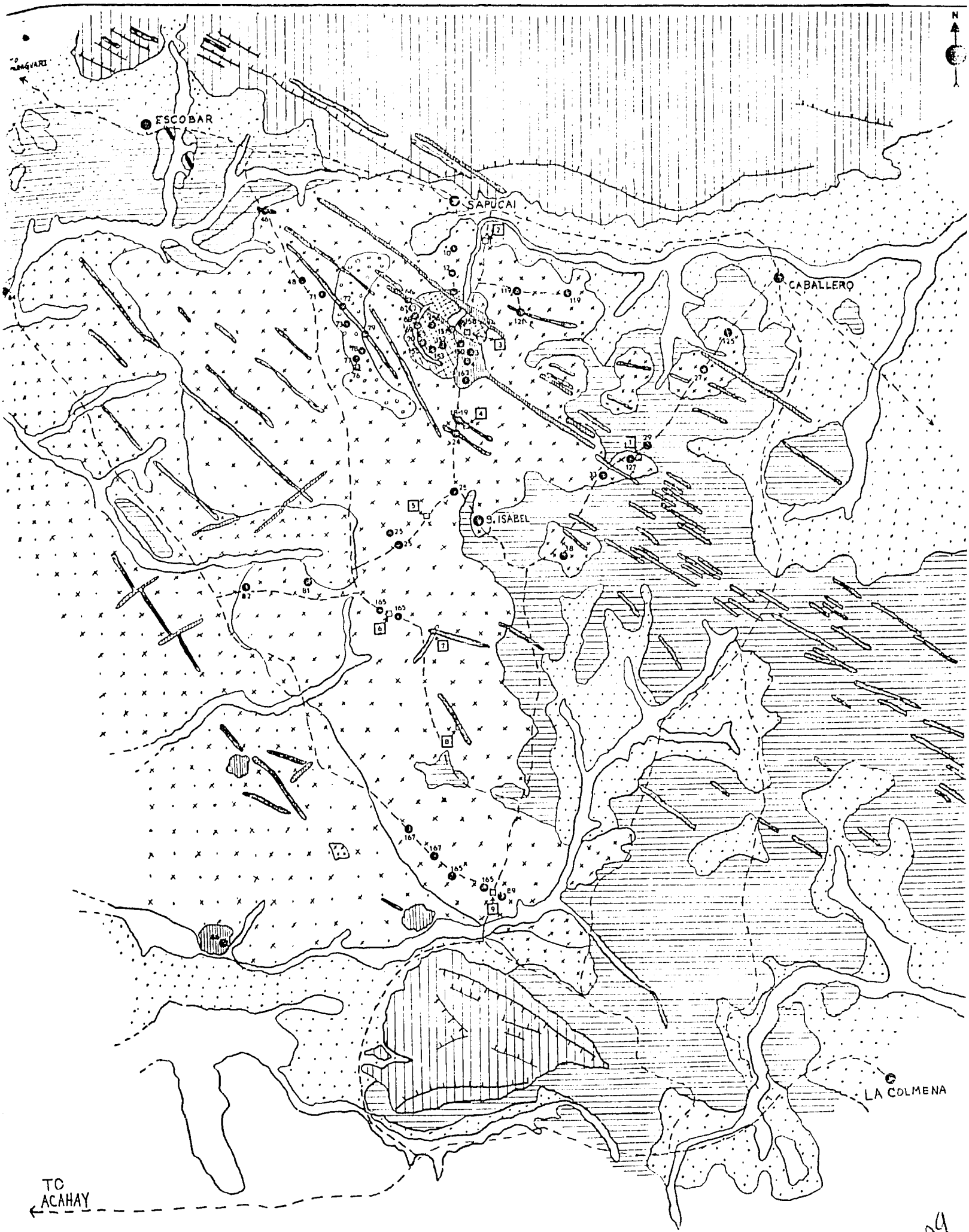
SCARP FAULTS
RING DIKE
DIKE SET (NW-SE)

SAMPLE STATIONS

ARRIBAS SERIES
PENAYO SERIES
ACCESS TRAILS & VILLAGES

(*) Based on data plotted by Arribas (Ref. 19)



REGIONAL SETTING

SCHEMATIC GEOLOGY OF SAPUCAI AREA