PN-ABM-937

International Fertilizer Development Center

Annual Report 1991

....maintaining sound research and development, technical assistance, and human resource development activities relevant to the needs of the developing countries.

Contents

Management Report 3
In Memoriam—Dr. John A. Hannah 5
Program Profiles 7
- Nutrient Characterization and Production Program 7
- Nutrient Dynamics and Agroecosystems Program 9
- Economics and Policy Program 22
- Information Management Systems Program 24
- Environmental Assessment Program 32

Regional Focus 33
- East and Southeast Africa 33
- West Africa 34
- Asia and Europe 42

Outreach 47
- Technical Assistance 47
- Human Resource Development 52

International Fertilizer Development Center 1991 Projects 58
Financial Report 61
Staff 68
IFDC Board of Directors 71
IFDC Addresses 72
Acronyms and Abbreviations 73

MANAGEMENT REPORT

The year 1991 at IFDC brought changes in the Center's direction. Employing approaches involving integrated nutrient management, issues concerning the environment, and the development of efficient agribusiness systems, IFDC continued its work to help preserve land resources to help ensure sustainable agricultural development.

Dr. Paul J. Stangel

New programs were implemented to provide solutions to the challenges confronted in the primary agroecosystems in the developing countries as they pursue sustainable agriculture. The objective of this new and broadened approach by IFDC is to embrace total nutrient management required to support effective land management and lead to sustainable crop production. The inclusion of agribusiness and expanded economics and policy in its portfolio of activities ensures that IFDC will continue to play a dynamic role in the developing countries by assisting with the establishment of appropriate agricultural policies and relevant technologies that will lead to agricultural and economic development that is equitable and sustainable.

Dr. Amit H. Roy

Collaborative arrangements between IFDC and several other organizations were forged or strengthened during the year. These agreements included cooperation with the International Council for Research in Agroforestry (ICRAF), the International Board for Soil Research and Management (IBSRAM), Biological Nitrogen Fixation Technologies for International Development (NifTAL), the International Rice Research Institute (IRRI), the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), and the Centro Internacional de Agricultura Tropical (CIAT). Activities arising from these collaborative arrangements would include research and training programs that will contribute to enhanced natural resource management and sustainable agricultural development in the tropics.

As a result of political and economic reforms in Eastern Europe and the former Soviet Union, IFDC's opportunities for providing technical assistance in these regions expanded. During 1991 IFDC participated in projects in Albania and the former Soviet Union. IFDC's technical assistance activity in the developing world expanded as well, with projects taking place in 11 countries.

Increasingly IFDC is positioning itself to provide practical solutions to the problems confronted by decisionmakers of the fertilizer and agricultural sectors in the most cost effective and efficient manner with a commitment to maintaining sound research and development, technical assistance, and human resource development activities relevant to the needs of the developing countries.

Paul J. Stangel

Amit H. Roy

IN MEMORIAM—DR. JOHN A. HANNAH

In 1991 the world of agricultural development lost a true giant with the death of Dr. John A. Hannah, the first Chairman of IFDC's Board of Directors.

Anyone who knew Dr. Hannah could not help but be struck by his true wisdom. This wisdom came shining through in a speech he delivered to a graduating class at Oklahoma State University in 1980. In that speech he said, "Having lived a fairly long life, I am convinced that only people are really important.... One of the most pervasive of all human desires for people of all races, all skin colors, all religions, and all economic philosophies everywhere is an instinctive aspiration for every human being to crave recognition as a dignified human being."

Also in that address, Hannah quoted Wendell Wilkie (an unsuccessful candidate for the U.S. Presidency in 1940), but the quote could just as easily have been his own: "To survive we must create a single world in which all people have the opportunity for a good life, a safe life, and a meaningful life—a world in which people matter."

This quote could serve as an appropriate epitaph for John A. Hannah. His life was an exercise in creating a better world for people all over the globe—a meaningful life and a world where people are important.

Dr. Hannah held so many distinctive positions and honors, it is impossible to mention all of them here. The graduate of Michigan State University held honorary degrees from more than 30 colleges and universities. From 1941 to 1969, he served as President of Michigan State University and was Administrator of the U.S. Agency for International Development (USAID) during 1969-73. He was heavily involved in the First World Food Conference in 1974 and was Executive Director of the World Food Council of the United Nations.

Having been the first Chairman of IFDC's Board of Directors, Hannah had a deep sense of commitment to and interest in the organization. In an interview with this writer in 1981, he shared some of his hopes and dreams for IFDC. In his down-to-earth manner, Hannah reminded the IFDC staff, "In everything we do, we should ask ourselves, 'Has this in it a potential to what we're supposed to be after?'"

Those of us who knew Dr. Hannah were impressed by his sense of vision. In his 1985 address during IFDC's Tenth Anniversary Celebration, he

focused our thoughts on the future when he said, "As we look back on the first decade, let us look forward to the end of the second decade when hopefully IFDC will be able to say the world's hungry countries and particularly Africa is recovering and that IFDC has played a significant role in *helping hungry nations of the world to stand on their own feet in looking forward to a peaceful and better fed world.*"

The last portion of this quote represents the essence of John A. Hannah's life. He will be missed by all who knew him.

Program Profiles

During 1991 the mission of IFDC was expanded to embrace the broader questions of integrated nutrient management, issues concerning the environment, and the development of an efficient agribusiness system in a deregulated, competitive marketplace and to continue the work on sustainability in agriculture. "Sustainability" simply means that "continued production from a specific agroecosystem depends upon maintenance and enhancement of resources on which production is based."

New IFDC programs were established and are in various stages of implementation. They were designed to provide solutions to the challenges confronted in the primary agroecosystems in the developing countries as they strive to attain sustainable agriculture. IFDC perceives these programs to be important areas for which the Center has comparative advantage in conducting them. These "building blocks of sustainable agriculture" include the following: nutrient characterization and production, nutrient dynamics and agroecosystems, economics and policy, information management systems, agribusiness, environmental assessment, human resources development, and project analysis and assistance. The first six programs are discussed in this section; the remaining two are included in the section on Outreach.

Nutrient Characterization and Production Program

This program emphasizes the research and development of both external nutrient sources (agrominerals and other raw materials; inorganic and organic fertilizers) and on-farm available nutrient sources (plant and animal residues). A broad spectrum of activities can be addressed by the staff members assigned to this program. A basic function of the program is the characterization of agromineral resources in terms of quantity, quality, suitability for direct application, potential for upgrading by beneficiation, and suitability as raw materials for fertilizer production. Capabilities exist within the program to further evaluate the processing characteristics of raw material feedstocks in the manufacture of compound, phosphate, and potash fertilizers. Other research in the program deals with the controlled release of nutrients and the development of potash fertilizers that have low-chlorine contents. Controlled-release nitrogen products are produced and undergo preliminary testing to assess their effectiveness as nitrogen sources. Organic residue and nitrogen research focuses on the evaluation of both on-farm and off-farm organic residues as sources of plant nutrients and their role in soil amendments.

Several major studies were completed during 1991 by staff involved in this program. A prefeasibility study that investigated the possibility of developing a mine, beneficiation plant, and a processing plant at the Matongo phosphate deposit in Burundi was completed for the Burundi Department of Mines and Geology.

IFDC geologists and a mining engineer traveled to Burundi several times to develop an ore-sampling program for the Matongo deposit. As a result of the sampling program, approximately 42 tons of phosphate ore was collected from several exploration pits. The 42 tons of ore was prewashed and sized in Burundi to produce five preconcentrate samples that represented the five major ore types within the deposit. Four of these preconcentrates (11.7 tons) were further beneficiated to produce 1.7 tons of 39.3 wt% P_2O_5 concentrate, 1 ton of 37.9 wt% P_2O_5 concentrate, and 0.2 tons of 40.7 wt% P_2O_5 concentrate. The beneficiation processes used to produce the concentrates involved washing and sizing, attrition scrubbing and sizing, flotation, and magnetic separation.

The Matongo concentrates were processed into single superphosphate (SSP) using a novel process that had been previously used in the SSP plant at Sukulu Hills, Uganda. In this process wet rock feed is acidulated with undiluted sulfuric acid (98%-99%). The most significant feature of this process is that phosphate concentrate from the beneficiation plant does not require drying before further processing. Partially acidulated Matongo phosphate rock was produced by granulating run-of-pile SSP with 75% solids content concentrate slurry. These products and a sample of finely ground phosphate rock concentrate were shipped to Burundi for agronomic testing.

The data generated by the IFDC geologic sampling program, beneficiation tests, and fertilizer production tests were used to design a mine, beneficiation plant, and combined SSP/partially acidulated phosphate rock (PAPR) processing plant. The capacity of the fertilizer-producing complex (24,000 tpy of run-of-pile or granular SSP or 21,000 tpy of granular PAPR) was based on a 15-year projection of demand for phosphate fertilizers in Burundi. Capital and manufacturing costs were analyzed under several scenarios. Discounted cash flow analyses were performed for the production of run-of-pile SSP and granular SSP based on the capital and manufacturing cost estimates and the 15-year market projection.

Based on the results of the IFDC study and recommendations, studies of the Matongo deposit are continuing. At the present time additional geologic studies are being performed to further delineate the Matongo ore body and firmly establish the amount of minable reserves.

An agromineral resource survey, "Evaluation of the Underdeveloped Phosphate Deposits of the Volta Basin and West Africa: Benin, Burkina Faso, Ghana, Mali, Mauritania, and Niger," was performed in collaboration with the Bundesanstalt für Geowissenschaften und Rohstaffe (BGR). This study produced an exhaustive report that reviews the geology and resources of agromineral deposits (phosphates, sulfur, potash, and nitrogen sources) and the development of agromineral projects in the region. The results of this report will be used to guide further agromineral development projects within the West African region.

A study was conducted for the Nauru Phosphate Corporation to assess the importance of remaining resources of residual phosphate ore after traditional reserves are depleted, potential uses for residual phosphate ore, and a strategy for leaving the mined-out areas in an environmentally acceptable form.

Batch-scale beneficiation tests were used to conceptually design a beneficiation plant to produce phosphate concentrates and determine potential capital and manufacturing costs for Sociedad Quimica y Minera de Chile, S.A. (SQM). The results of the SQM study indicated that the processing of apatite-rich fines from an iron ore pelletizing operation in Chile was not economically viable under the conditions of the study.

Beneficiation tests were conducted on Chilembwe phosphate ore, Zambia. These tests were used to implement a pilot plant-scale program, which produced phosphate concentrates that were eventually used for the production of experimental fertilizers to be used for agronomic testwork in Zambia.

Chilembwe phosphate ore that assayed 20.3 wt% P_2O_5 was upgraded to 33.7 wt% P_2O_5 by flotation. Approximately 1.7 tons of Chilembwe ore was processed to obtain 0.6 tons of concentrate. All of the concentrate was ground in a ball mill to pass about 80% by weight 200-mesh screen opening. One portion of the ground ore was acidulated and granulated to prepare a PAPR-50. Another

Dr. Deborah T. Hellums, IFDC Research Associate, conducts the participants in the training program "Plant Nutrient Management for Sustainable Agriculture" on a tour of the IFDC greenhouses.

(Photo by Charles Butler)

portion of the concentrate was compacted with SSP to prepare a simulated PAPR-50.

Batch laboratory-scale and pilot-plant tests were conducted on Riecito phosphate ore for Instituto de Technologica de Venezuela Petroquimica (INTEVEP), Venezuela. Beneficiated Riecito phosphate rock and processing residues (slimes) were evaluated for use in the production of wet-process phosphoric acid. Five Venezuelan engineers were trained in conjunction with this program.

A significant effort was required to develop and install a nitrogen laboratory for the Egyptian Fertilizer Development Center (EFDC) and train Egyptian laboratory personnel. Several individual training programs were also conducted at IFDC in 1991. A Mauritanian geologist and a Togolese agronomist were trained in phosphate rock characterization techniques. An Indian chemical engineer was trained in the coating of urea. Assistance was also provided during several Outreach training programs.

Research activities centered around the United Nations Development Programme (UNDP) Global Project. Twenty rocks from phosphate rock deposits around the world were analyzed for their contents of arsenic, cadmium, chromium, mercury, lead, selenium, uranium, and vanadium. These data were analyzed and added to a large data base that is being developed on the potentially hazardous element contents of phosphate raw materials, intermediates, and fertilizer products. Tests were conducted to determine the distribution of potentially hazardous elements in the production of wet-process phosphoric acid using two West African phosphate rocks. The purification of phosphoric acid produced from these rocks was also investigated.

Greenhouse and field experiments were continued to investigate the use of urea supergranules and urea-DAP supergranules for rice. Research continued into the coating of urea granules with various polymer products. Collaborative studies investigating the use of starch in polymer membranes were instituted with the University of Southern Mississippi, Department of Polymer Science.

Experimentation continued on the production of low-chlorine potassium fertilizers. The process being investigated uses potassium chloride and waste phosphogypsum to produce potassium sulfate.

Literature searches and preliminary experiments were performed concerning the development of organic fertilizers from selected agroindustrial wastes. Investigations centered around the use of coconut husks, rice hull ash, and sugarcane bagasse. Also being investigated is the use of leonardite, a form of oxidized coal, as a component of organic fertilizers.

Planned activities for this program in 1992 include identification of heavy metals in fertilizer raw materials, characterization of agromineral deposits (mainly from Africa), and the development of controlled-release fertilizers. Additional research will be undertaken for characterizing organic matter residue and the development of organic-based fertilizer products. Some of this work will be done under the UNDP Global Project.

Nutrient Dynamics and Agroecosystems Program

The nutrient dynamics and agroecosystems program seeks to improve or maintain crop production in diverse cropping systems in a sustainable and environmentally acceptable way through the removal or reduction of soil fertility constraints that exist under different tropical and subtropical conditions. Increased and sustained crop yields are achieved through improved nutrient supply systems that maximize efficiency of nutrient use by reducing losses of nutrients, improving nutrient cycling, and integrating inorganic fertilizer use with organic and biological inputs such as biologically fixed nitrogen. This program evaluates the impact of fertilizer and overall nutrient management practices on the environment and develops or improves diagnostic techniques for optimizing the efficiency of nutrient use while minimizing environmental impact and delineating and forecasting deficiencies or problems that arise.

Use of Indigenous Resources of Phosphate Rock

Greenhouse Research

Evaluation of Nonconventional Phosphate Fertilizers

A greenhouse study was conducted to compare the effectiveness of three phosphate rocks (Hahotoe, Togo; Tilemsi, Mali; and Sechura, Peru, representing three levels of reactivity—low, medium, and high, respectively) along with partially acidulated forms of Hahotoe phosphate rock, a granular mixture of Hahotoe phosphate rock and triple superphosphate (TSP) made by compaction, SSP, magnesium-oxide-treated SSP (Fosmag), and ammoniated triple superphosphate (ATSP) with the effectiveness of TSP as sources of phosphorus nutrition for maize on a phosphorus deficient-acid (pH = 4.5) soil. All treatment including the control received blanket applications of the nitrogen, potash, and the micronutrients.

Yields for the initial crop verified an overall correlation between the relative agronomic effectiveness (RAE) of the nonconventional materials and the amount of available phosphorus (water + citrate soluble) in the product (Table 1). Additionally, all results support the fact that the expensive production of the amounts of water-soluble phosphorus common to conventional phosphate fertilizers (SSP and TSP) was not necessarily required for maximum RAE. The PAPRs with one-half the amount of water-soluble phosphorus (42% and 46%) found in TSP produced 65% and 67% of the RAE values associated with the use of TSP. In addition, the mixture of Hahotoe phosphate rock and TSP granules made by compaction (1:1 phosphorus ratio from each component plus urea and KCl), with levels of available phosphorus similar to the PAPRs, produced yields equivalent to those attained with TSP. The higher RAE value for the mixture relative to the PAPRs supported earlier findings that indicated phosphate rock mixed with urea increased phosphorus availability. Preliminary tests have shown that during urea hydrolysis there may be a corresponding temporary hydrolysis of soil organic matter that enhances dissolution of phosphorus from the phosphate rock by chelating calcium ions.

The final two products, ATSP and Fosmag, also produced RAE values equal to TSP for the initial maize crop. Again, the performance of the ATSP indicates that on acid soils the levels of water-soluble phosphorus common to SSP and TSP are not required for maximum crop production. The RAE value obtained for Fosmag indicated that on this particularly acid soil with a phosphorus retention rate of 35% the citrate-soluble phosphorus component (72%) was a major contributor to the plant's phosphorus nutrition needs. The ability of citrate-soluble phosphorus (which becomes more available with time) to meet some of the plant's phosphorus requirements in the initial crop was also supported by the performance of the phosphate rock sources (Hahotoe, Tilemsi, and Sechura), where increasing levels of reactivity resulted in increasing RAE values.

The residual value of the citrate-soluble phosphorus became more apparent with the second maize crop where all nonconventional sources except those composed primarily of citrate-soluble phosphorus showed a decrease in RAE.

In summary, the results suggest that for acid soils of the tropics nonconventional phosphorus fertilizers developed from indigenous sources can play a vital role in sustaining or improving food production. There is also evidence that levels of water-soluble phosphorus associated with conventional fertilizers may not be needed to support maximum yield on many soils in this region. If this finding translates to agriculture in the temperate regions (as present evidence suggests), acceptance of lower levels of water-soluble phosphorus could result in major economical and environmental benefits. The final result derived from this experiment and a followup study was that materials possessing high levels of citrate-soluble phosphorus relative to low levels of water-soluble phosphorus can be more agronomically effective than conventional fertilizers for residual or long-term crops on acid soils with high levels of phosphorus retention. In developing countries with large areas of soil possessing such characteristics, these nonconventional fertilizers may offer an economic alternative to the more costly practice of applying large amounts of soluble phosphorus.

Table 1. Chemical analysis of phosphate fertilizers and their relative agronomic effectiveness (RAE)

Phosphorus Source†	Phosphorus: Citrate Soluble	Phosphorus: Water Soluble	Relative Agronomic Effectiveness (RAE)•*: Harvest 1	Relative Agronomic Effectiveness (RAE)•*: Harvest 2
	- -(% Total P_2O_5)- -		- - - - - -(%) - - - - -	
Hahotoe phosphate rock, Togo	10	<0.01	4 f	13 f
Tilemsi phosphate rock, Mali	20	<0.01	29 e	52 c
Sechura phosphate rock, Peru	32	<0.01	53 d	100 b
Togo PAPR 20% H_3PO_4				
Togo PAPR 50% H_2SO_4				
Togo phosphate rock + SSP + urea + KCl	14	40	104 a	60 c
Fosmag	72	24	90 ab	137 a
Ammoniated TSP	23	55	99 a	39 d
SSP (commercial grade)	16	84	97 a	98 b
TSP (commercial grade)	15	85	100 a	100 b

† PR = phosphate rock; PAPR = partially acidulated phosphate rock.
• Values followed by the same letter in each column are not significantly different (P = 0.05).
* Relative agronomic effectiveness (RAE)

$$= \frac{\text{Yield from the P being tested - yield from control}}{\text{Yield from TSP - yield from control}} \times 100$$

Utilization of Dorowa Phosphate Rock From Zimbabwe

During 1990/91 a soil scientist from Zimbabwe conducted greenhouse experiments at Headquarters on the agronomic effectiveness of nonconventional phosphate fertilizers produced from the Dorowa phosphate rock from Zimbabwe. The results showed that Dorowa phosphate rock was a poor source of phosphorus for both maize (Figure 1) and ryegrass (Figure 2). The Dorowa rock, which was compacted with TSP at P_2O_5 ratio = 50:50, urea, and KCl, resulted in a phosphate fertilizer source that was as effective as SSP mixed with urea and KCl in increasing dry-matter yield of maize and ryegrass (Figures 1 and 2) on an acid soil. Dorowa partially acidulated (at 50% level with sulfuric acid) rock mixed with urea and KCl was 75% as good as SSP for maize (Figure 1) and for ryegrass (Figure 2). The results clearly showed that other alternative technology can be adopted to produce cost-effective phosphate fertilizers for crop production using indigenous phosphate rocks in some developing countries.

Results of Phosphate Rocks Mixed With Superphosphates

Phosphate rock deposits occur in several developing countries. Most of them, however, are of low quality and need to be altered chemically to render them effective as fertilizers. IFDC research has shown that some phosphate rocks altered by partial acidulation approached the effectiveness of superphosphate; others such as Capinota phosphate rock from Bolivia were far less effective. This was attributed to the presence of large amounts of iron and aluminum oxides in the phosphate rock. These oxides will react with part of the acid added for acidulation, thereby reducing the amount of acid available for reaction with phosphates. Additionally, part of the soluble phosphate formed due to acidulation will react with iron and aluminum and revert into insoluble forms. Mixing such types of phosphate rocks with superphosphates appears to be more agronomically effective compared with partial acidulation; compaction is a convenient method of making granules of these mixtures.

In greenhouse trials using PAPR prepared by treating five phosphate rocks with iron and aluminum oxide contents ranging from 2% to 32% with 50% of the acid needed to convert all the phosphates to superphosphates, the PAPRs were only 85% to 12% as effective as TSP for maize grown in acidic soil. In contrast, the granulated mixtures made by compaction of these rocks and TSP with TSP providing 50% of the phosphorus in the mixture were 80%-100% as effective as TSP (Table 2).

The progressive reduction in the effectiveness of the PAPRs with increasing amounts of iron and aluminum oxides was due to the decrease in soluble phosphorus content in the PAPR. Instead of the expected 50% of the total phosphorous being soluble at 50% acidulation, the soluble phosphorus content of the PAPR ranged from 51% to 10%.

Table 2. Influence of iron oxide and aluminum oxide in phosphate rock on the effectiveness of PAPR

PR	% Fe_2O_3 + Al_2O_3	Product Used	Dry-Matter Yield of Maize (g/pot)
TSP	0.0		40.32
Togo	2.0	PAPR	34.56
		PR+TSP	34.31
Tennessee	6.6	PAPR	24.53
		PR+TSP	39.10
Mali	8.5	PAPR	27.41
		PR+TSP	41.01
Niger	9.9	PAPR	21.01
		PR+TSP	36.86
Burundi	32.0	PAPR	6.63
		PR+TSP	32.91

This study confirms that countries such as Niger and Burundi, which have deposits of phosphate rocks containing large amounts of iron and aluminum oxides, can make effective use of these natural resources for sustainable agricultural production by mixing them with soluble phosphates. Granules can be made by compaction or other methods. Compaction is a convenient and relatively simple method for converting dry solid materials into granules which is under evaluation for application in developing countries.

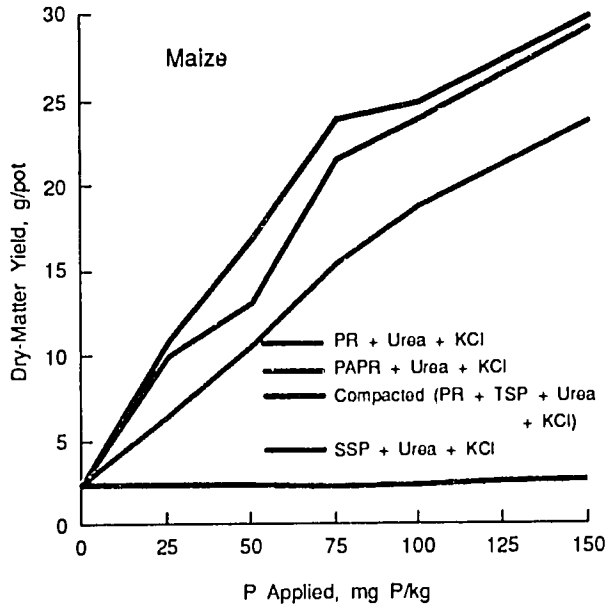


Figure 1. Dry-matter yield of maize obtained from modified Dorowa phosphate rock (PR) from Zimbabwe and single superphosphate (SSP).

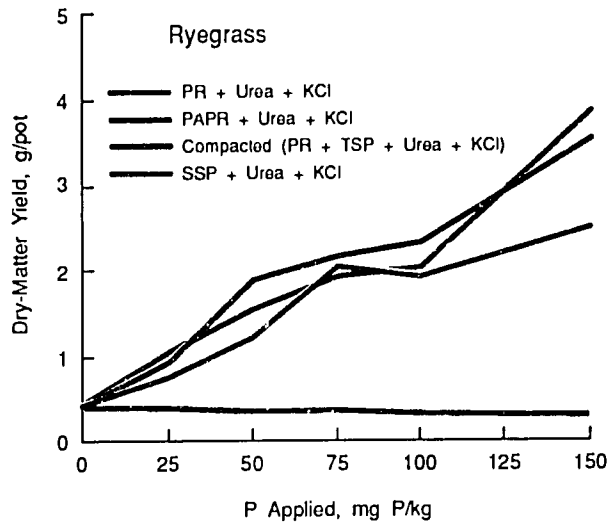


Figure 2. Dry-matter yield of ryegrass obtained with modified Dorowa phosphate rock (PR) from Zimbabwe and single superphosphate (SSP).

Keith Tays conducts experiments to evaluate nutrient availability on rice yields in the IFDC greenhouse.

(Photo by Charles Butler)

Field Evaluation Research

The P_i Test

For the past few years, IFDC scientists have been evaluating an innovative test procedure, the P_i test, for measuring phosphorus-supplying capacity of soils. The test, which has potential as a universal soil test for phosphorus, makes use of paper strips coated with iron oxides to trap and remove phosphorus present in a soil-solution suspension. The test has received wide acceptance among scientists in Asia, Africa, and Latin America, and in Australia and New Zealand as a research tool, especially to evaluate phosphorus availability in soils fertilized with alternative phosphorus fertilizers. Field studies are being carried out by IFDC scientists and collaborators to calibrate the P_i test and formulate indexes for fertilizer recommendations.

Research has now shown that the P_i test is a simple and effective test for measuring phosphorus in water and sediments from aquatic bodies. The paper strips act as a phosphorus sink, aid in concentrating the small amounts of phosphorus found in water, and permit its effective extraction and evaluation. Phosphorus measured by the P_i method showed very close correlation with that by conventional method. The P_i test has the advantage that phosphorus can be extracted from rivers, lakes, and agricultural runoffs, etc., by placing the paper strips in measured volumes of water, or *in situ* and the strips sent to the laboratory for analysis, thus eliminating the need to send water samples. Thus, the test has good potential for use in monitoring phosphorus pollution in aquatic ecosystems.

East and Southeast African Fertilizer Management and Evaluation Network

Since its inception IFDC has pioneered work on the characterization and effective use of indigenous agrominerals such as phosphate rock. The East and Southeast African Fertilizer Management and Evaluation Network (ESAFMEN) was established in 1987 initially to explore the agromineral deposits of the region for use as fertilizers or soil amendments to increase and/or sustain soil productivity. Since phosphate deposits are widespread (Figure 3) and phosphorus is one of the most limiting nutrients in the region, initial ESAFMEN efforts have concentrated on using these sources of rocks.

Field trials using the ground phosphate rocks, partially acidulated phosphate rocks, and compacted mixtures of phosphate rocks and superphosphates showed that for pasture, different species utilize phosphorus sources differently. For example, at Soddo in Ethiopia, response of lucerne to phosphorus was low; nine cuttings yielded a total of 2.4 t/ha. However, when lucerne was replaced by Desmodium species, the mean yield for a single cutting was 2.2 t/ha, and the response to residual phosphorus was substantial.

At Katumani in Kenya, Minjingu phosphate rock from Tanzania was found to be 60% as effective as SSP in increasing maize grain yield, whereas Minjingu PAPR at 50% acidulation was equally as effective as SSP (Figure 4). In Zimbabwe, both the reactive Minjingu phosphate rock and the less reactive indigenous Dorowa phosphate rock were 61% to 78% as effective as the superphosphates in three medium-acid soils.

The results of these trials indicate that indigenous phosphate resources have substantial residual value and are useful in maintaining sustainable agricultural production. Annual applications of the phosphates appear to produce the best results. A single, high-rate application, however, could give satisfactory crop yields over a 2- to 3-year cropping cycle.

Latin America

During 1991, one of the most important objectives of the IFDC/Centro Internacional de Agricultura Tropical (CIAT) soil fertility studies in Latin America was to search for the best phosphate fertilizer management in acid soils of the tropics in order to avoid pollution, to increase and conserve soil fertility, and to obtain a productive and sustainable cropping system. For this reason major efforts were concentrated in the field experiments where different phosphate sources were used and the residual effects were studied.

Phosphorus Research—Very important crops such as potatoes, beans, upland rice, and maize were used in high-, medium-, and low-altitude regions, respectively, to study the residual effects of phosphate fertilizers classified as materials with low, medium, and high reactivity and agronomic effectiveness. Results from an experiment with beans (three crops) were used to study the economics of continuous application of phosphate fertilizers in low available phosphorus and high phosphorus-fixing soils of the Andean mid-altitude region of Colombia. Residual effects of PAPR and compacted phosphate rock with TSP from Huila, Colombia, and Capinota, Bolivia, were evaluated for crops such as upland rice in rotation with soybeans and maize on Oxisols of the Eastern Plains of Colombia. In addition, one experiment with potatoes was established on an Andisol from the high-altitude region of the Andes in the southern part of Colombia.

Field experiments were used for the calibration of the P_i test. Also greenhouse studies to test the P_i method under flooded conditions, using several soils from areas of Colombia where lowland rice is generally growing, continued. Preliminary tests of the P_iE method (embedded impregnated paper strips), a simple and reliable procedure, were performed.

Results from the residual beans and pasture experiments in Morales showed that the PAPR materials and the phosphate rock mixtures made by compaction performed as well as TSP. An economic evaluation of the results obtained showed that the best treatments were those with TSP, applied every semester at a low phosphorus rate

Chris N. Butegwa (right) from Uganda receives training from Dr. R. G. Menon, IFDC Soil Scientist, in the preparation and use of P_i strips for phosphorus evaluation.

(Photo by Charles Butler)

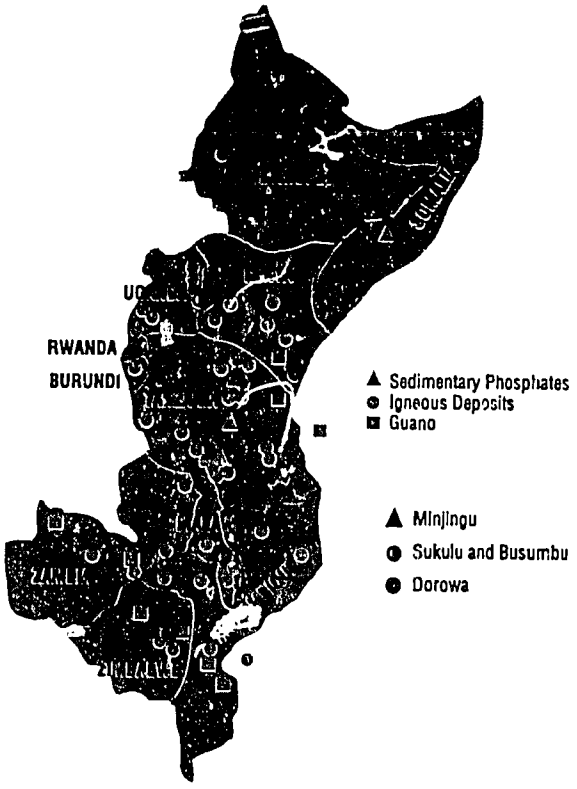


Figure 3. Phosphate deposits of east and southeast Africa.

(50 kg/ha) or in one initial application at planting time to the first crop at a high phosphorus rate (150 kg/ha). Periodic applications of phosphorus (every semester) produced higher additional income than only one application before the establishment of the first crop. Finely ground phosphate rocks presented the lowest economic yields. It is necessary to use a mixture of rock with TSP or to partially acidulate the phosphate rocks in order to get positive additional income. Applications of the above sources showed that, for maize and an upland rice-soybean rotation, PAPR and granular phosphate rock mixtures made by compaction performed better or as well as TSP. The residual effect of Huila phosphate rock on soybeans after rice was outstanding, the same as the residual effect of partially acidulated Huila phosphate rock on soybeans after rice-soybeans-rice. The potato experiment showed similar yields for Capinota PAPR, compacted Capinota PR+TSP, and TSP at the annual rate of 200 P_2O_5/ha of application.

Nitrogen Research—Nitrogen research concentrated on the testing of coated urea and urea + NBTPT at the Instituto Colombiano Agropecuario (ICA) Nataima Experiment Station under three irrigation practices. Yield results obtained indicate that, even though the effect of the urease inhibitor did not last for a long period of time, it was at least somewhat effective, producing an increase of 500 kg of paddy rice per ha, when the water was applied 3 days after urea application.

Sulfur Research—A field study (ICA and Monomeros Colombo Venezolanos, S.A. [MONOMEROS]) indicated that many of the Andepts contain low levels of sulfur. This problem must be addressed in future studies.

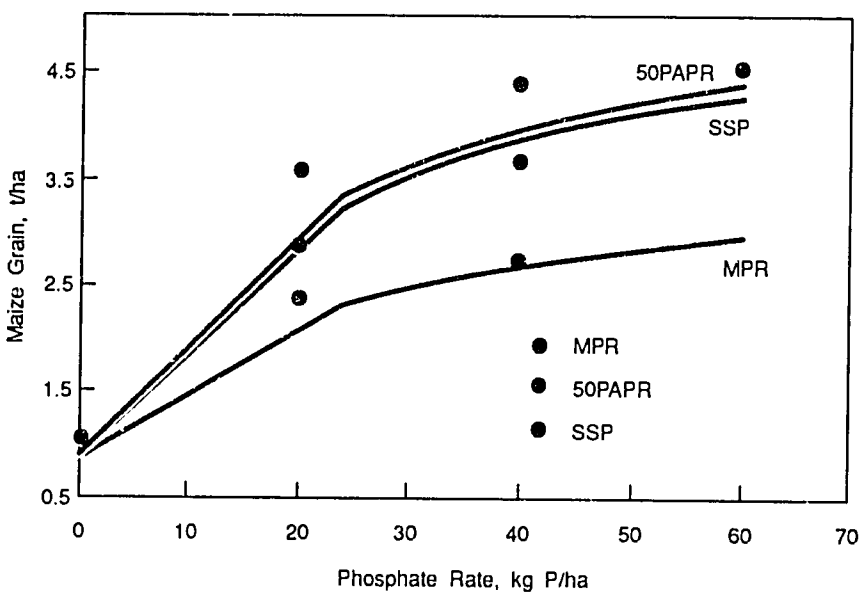


Figure 4. Maize grain yields obtained with Minjingu phosphate rock (MPR) from Tanzania, partially acidulated MPR at 50% acidulation with sulfuric acid (50% PAPR), and SSP at Katumani in Kenya.

Environmental Issues

The Effects of Fertilizers on "Greenhouse Gas" Emissions

Widespread concern about the buildup of so-called "greenhouse gases" in the earth's atmosphere, which is predicted to cause a warmer and more erratic global climate, has prompted IFDC scientists to evaluate the effect of fertilizers on the emission of two gases from flooded rice fields. These two gases, methane and nitrous oxide, are thought to account for a major share of the gas emissions from agricultural sources. IFDC scientists are studying the sources of these gases, their transport from the soil, and the effects of chemical fertilizers on the emission of the gases.

Methane Emissions

Fertilizer additions to rice generally increase methane emissions from flooded rice because a larger rice plant produces more root exudates, which are the source of carbon used by bacteria in the soil to produce methane. Research by IFDC scientists showed that sulfate-containing fertilizers can decrease emissions while nitrogen fertilizers generally increase them (Figure 5). It is not clear as yet whether rice yield and methane emissions are directly related or if the methane emission increases at a slower rate than yield increases. The results at IFDC indicate that while sulfate can reduce emissions large amounts of sulfate are necessary to create a significant effect, and there can be adverse effects of adding large amounts of sulfate to certain flooded soils.

The rice plant not only produces the root exudates used by the bacteria to produce methane, but the vacuous structure of the rice plant (aerenchyma cells) also functions as a "chimney" to carry methane from the soil to the atmosphere. IFDC scientists used a specially constructed chamber to determine if transpiration of soil water which is saturated with methane, might be the mechanism by which methane enters and moves through the plant. They changed the water transpiration rate of the plant by changing the humidity within the chamber, while keeping other factors such as light and temperature constant. They found that the amount of methane carried through the plant did not change as the transpiration rate changed (Figure 6). This indicates that methane does not move into or through the plants with the water, and gas diffusion is the likely transport mechanism. IFDC is continuing the research to corroborate these results and to provide more basic information on methane sources and the effects of fertilizers.

Nitrous Oxide Emissions

Most of the world's rice is grown under monsoonal climatic conditions with well-defined wet and dry seasons. During the dry season, rice is frequently not grown because sufficient amounts of irrigation water are not available. In the dry-season fallow period, the soil conditions are favorable to first accumulate nitrate and then to produce nitrous oxide from the nitrate as the soil becomes wetter at the end of the dry season. The soil is compact because it was puddled to grow the previous crop of rice, and it contains concentrated zones of readily decomposable organic matter in the roots of the rice hill; both of these conditions are conducive to nitrous oxide production.

Measurements of nitrous oxide emissions caused by the wetting of rice soils have not been reported; thus, IFDC scientists measured nitrous oxide emissions, nitrate formation, and the development of reduced soil conditions as the rice soil became wet by simulated rainfall. The soil conditions at first favored the accumulation of high amounts of nitrate. As the soil became wetter, nitrous oxide emissions began within a few days of each water addition (Figure 7). Nitrous oxide emissions were extremely high, about 7 kg nitrous oxide-nitrogen per hectare, which is higher than the highest previously reported annual emissions for a marsh soil.

The nitrogen fertilizers added to the previous rice crop had little effect on nitrous oxide emissions since the nitrate was derived from organic matter in the soil rather than from fertilizer. Nitrous oxide emission stopped as soon as the soil became saturated, even though a large amount of nitrate still remained in the soil. IFDC scientists continue their research to determine the influence of rainfall timing and intensity on nitrous oxide emissions from dry-season fallow soils.

Nitrogen Losses and Efficiency

Past research has shown that the reduction of losses of nitrogen from flooded rice systems is essential to improve efficiencies of fertilizer use. It

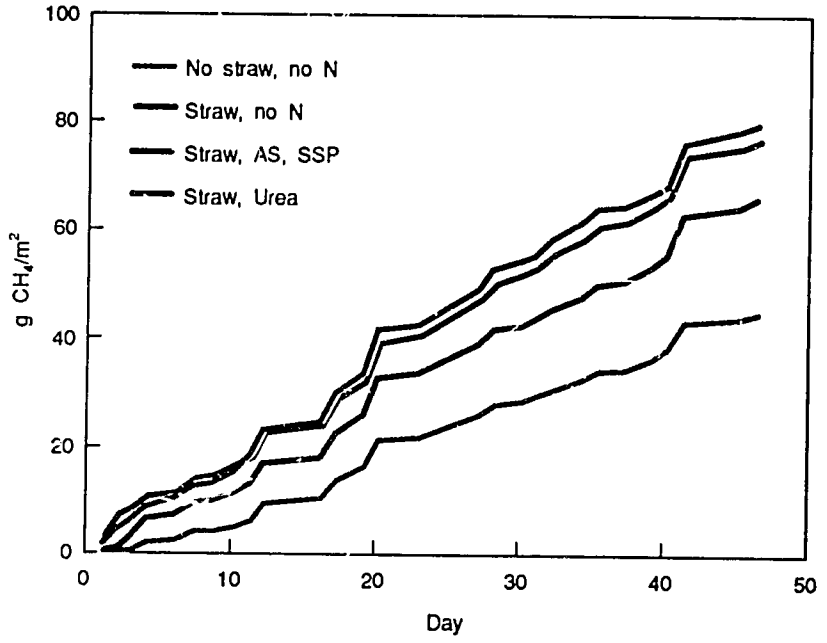


Figure 5. The effect of fertilizers and straw on methane emissions.

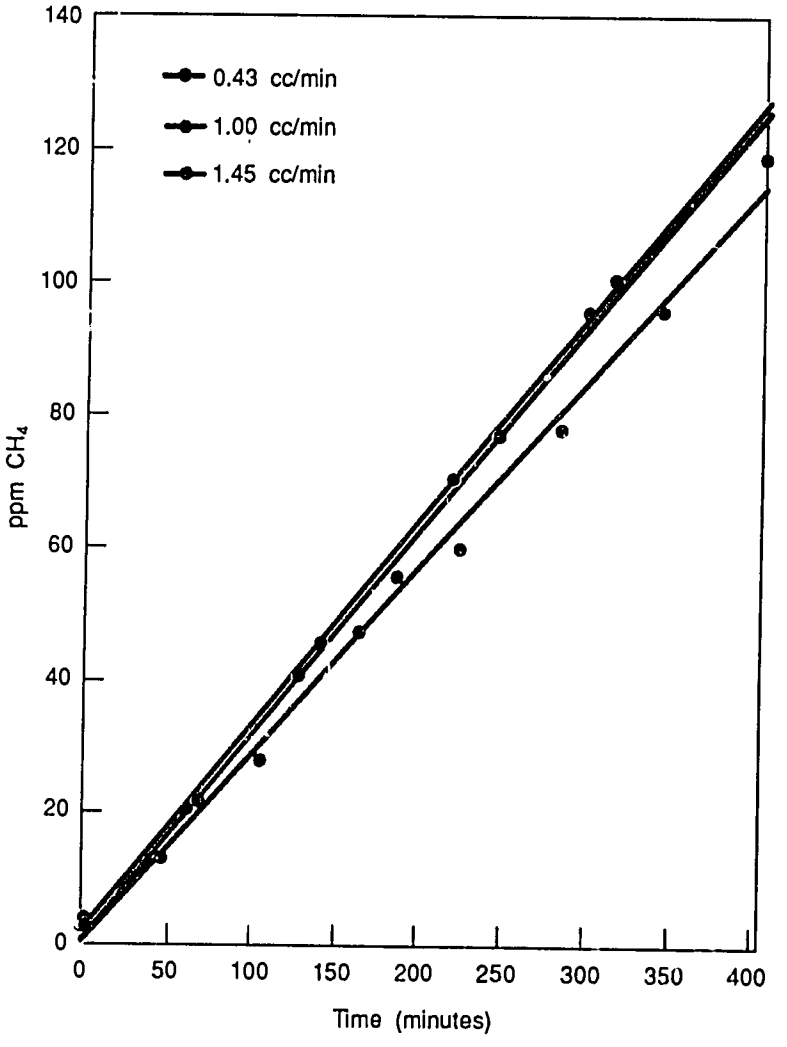


Figure 6. The effect of water transpiration rate on methane emissions.

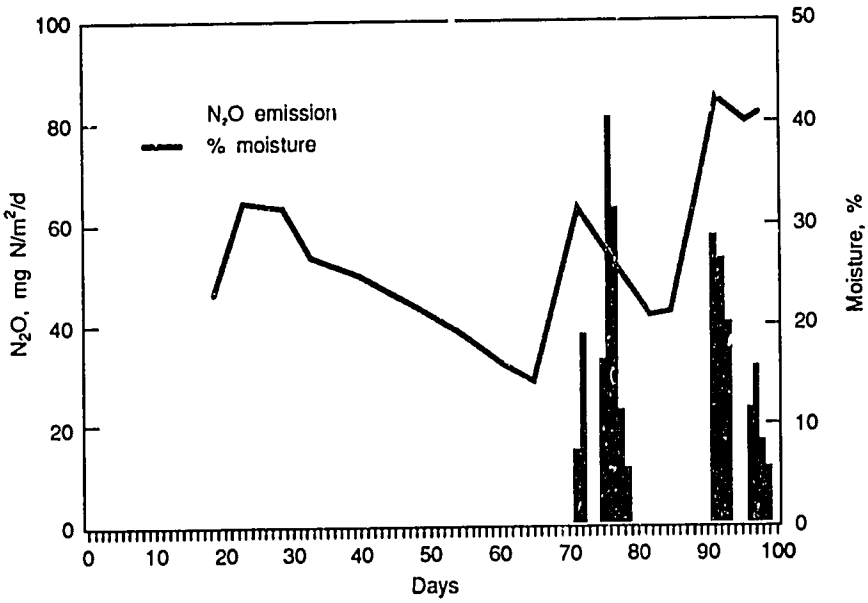


Figure 7.
Nitrous oxide emissions following a simulated dry season.

has become clear, however, that reduction of losses does not ensure high efficiency, and the timing of the availability of fertilizer nitrogen is very important. Too much nitrogen early in plant growth causes excess numbers of tillers, which later either die or are not very productive. Ultimately plant growth and grain production depend on how much sunlight can be intercepted and the optimum development of the number of tillers, grain head size, and grain filling can greatly improve rice yields, given a certain amount of available nitrogen.

The availability of the nitrogen from urea supergranules and sulfur-coated urea is apparently conducive to developing an efficient plant, and other methods of delivering nitrogen to the plants have not been as consistently successful at producing high yields even though they may limit nitrogen losses.

IFDC scientists are working with greenhouse methods to deliver nitrogen at specific times to rice plants. By controlling the temporal availability, the scientists will be able to determine the critical physiological stages of growth at which nitrogen availability affects rice yields. This information is essential to determine desirable release rates from coated or controlled-release fertilizers or to help recommend better timings of ordinary urea topdress applications.

Soil Fertility Research

Soil Fertility Management for Lowland Rice

In the early and mid 1980s, soil fertility research at IFDC focused heavily on management of inorganic fertilizer inputs and identification of strategies to increase their effectiveness. Priority for IFDC/International Rice Research Institute (IRRI) collaboration was given to nitrogen and to reducing the high gaseous losses from urea-N applied to flooded soils. Significant progress has been made in understanding nitrogen transformation processes, in identifying ammonia volatilization as a major nitrogen loss mechanism, and in recognizing the importance of nitrogen fertilizer placement. The focus on all this research was on inorganic nitrogen sources with little emphasis on other sources of the nutrient.

Environmental concerns about the high inputs for production led to a shift in research strategies toward the substitution of inorganic nitrogen fertilizers with organic nitrogen sources such as Azolla and green manures. Considerable progress has been made in developing the potential of biological nitrogen fixation (BNF) to substitute for urea to meet crop requirements by flooded rice.

It is now recognized that rice derives nutrients from, in addition to inorganic fertilizers, soil reserves, organic inputs including weeds and crop residues, and BNF. Research by IFDC scientists

strives to effectively use nutrients available from the soil and promote BNF, as well as to use inorganic fertilizers efficiently.

Collaborative IFDC/IRRI research has demonstrated that nutrient transformation processes in the soil are somewhat similar for both irrigated and rainfed lowland rice production. In both cases application of urea, while the soil is saturated or flooded, can result in rapid, large gaseous losses of nitrogen. When urea is basally incorporated or broadcast 11 days after transplanting (DT), 35%-45% of the urea-N is lost, presumably as ammonia, by 20 DT (Figure 8). Soil drying at 15 to 35 DT and subsequent reflooding lead to even greater gaseous loss than under continuous flooded conditions. This additional loss of nitrogen was presumably through nitrification and subsequent denitrification.

Other research showed that nitrogen and sulfur from applied fertilizers can be lost by runoff when rainfed lowland rice fields are inundated from heavy rainfall soon after fertilization. Runoff losses are higher from light- than from heavy-textured soils because a larger proportion of the nutrients are in the floodwater rather than sorbed to the soil.

Soil, water, and crop management practices imposed between rice crops can greatly influence the availability of soil nutrients to rice. This is particularly true where long fallows or periods of upland cropping occur between rice crops. Therefore, a major research thrust has been to understand how fallows, crop establishment practice, soil drying and wetting, and crop sequences influence soil fertility and nutrient availability for rice.

This research has shown that fertilizer recommendations for rainfed lowland rice on soils deficient in nitrogen and phosphorus should be different, depending on the rice establishment practices. Wet seeding of rice on puddled soil (WSR) resulted in greater use of soil-derived nutrients than dry seeding of rice before soil puddling (DSR), as evidenced by higher yields in the absence of nitrogen and phosphorus fertilizers (Table 3). Soil flooding and puddling before establishment of the rice crop increased the availability of both nitrogen and phosphorus. Phosphorus fertilizer increased yields much more in DSR than WSR. Combined use of inorganic fertilizers containing both phosphorus and nitrogen was essential for high yields in both DSR and WSR.

Fertilizer use is low on rainfed lowlands and it becomes more important that soil nutrients and BNF be collectively utilized. IFDC/IRRI collaborative research has been conducted to identify management practices to effectively cycle soil nutrients to rice through incorporated plant tissues. This work has shown that weed residues can supply nitrogen to a subsequent rice crop as well as conserve nitrogen in the system (Figure 9). The higher yield

Figure 8. Effect of flooding conditions on nitrogen losses from rice in the Philippines.

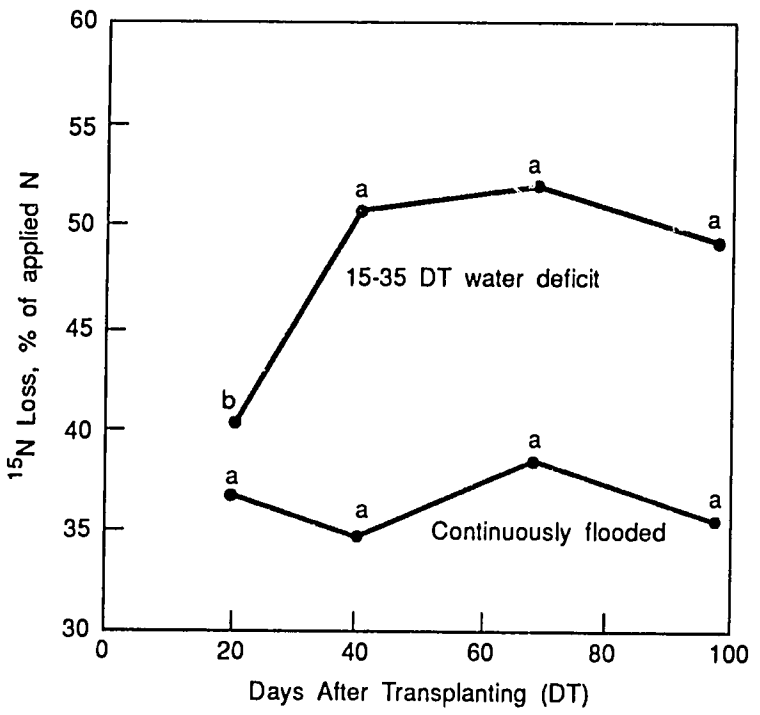


Table 3. Effect of fertilizer source and rice establishment method on rainfed lowland rice yield, Philippines

Year	Establishment Practice	Grain Yield Without N and P Fertilizers	Grain Yield Increase +N	+P	+NP
		(t/ha)	-----(t/ha)-----		
1990	DSR	0.7	-0.2	2.1	2.7
	WSR	2.2	-0.4	1.0	2.6
1991	DSR	0.8	-0.2	1.8	3.2
	WSR	2.0	0.6	0.4	1.3

DSR = dry-seeded rice.
WSR = wet-seeded rice.

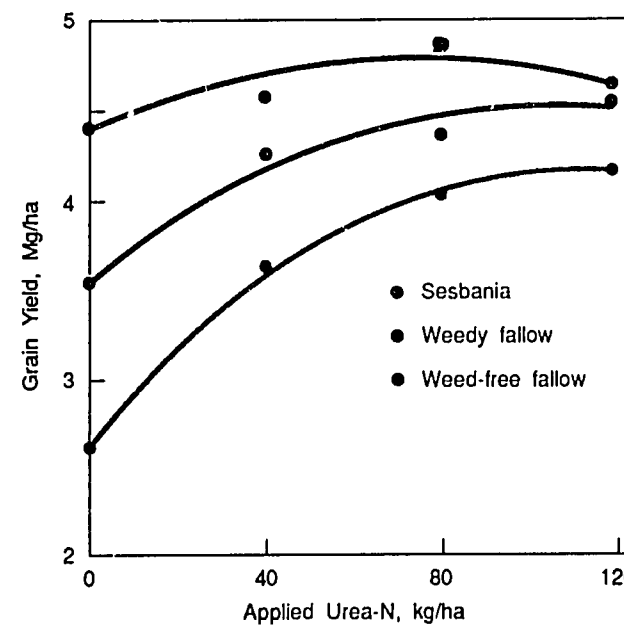
following weedy fallow compared with weed-free fallow was attributed to assimilation of soil nitrate by the weed, which would otherwise have been lost when the soil was flooded. The organic nitrogen becomes available to the rice crop through decomposition of the incorporated weed residue.

In environments such as favorable rainfed and irrigated lowlands where fertilizer use is high, IFDC scientists are attempting to increase the plateau in the yield response to applied nutrients by better timing and management of inorganic fertilizers and by improved crop management. These favorable sites will continue to require substantial quantities of urea to be productive.

Fertilizers to Correct Sulfur Deficiencies for Rice in Bangladesh

It is estimated that 80% of the soils in Bangladesh are deficient in sulfur. Currently, the sole source of fertilizer sulfur there is byproduct phosphogypsum derived from the production of triple superphosphate. There remains a large gap between use and estimated requirements to correct sulfur deficiencies and, if the growth rate in gypsum consumption seen in recent years continues, demand will exceed supply by the mid-1990s. During the last 3 years, IFDC has conducted field trials in collaboration with scientists at the Bangladesh Agricultural

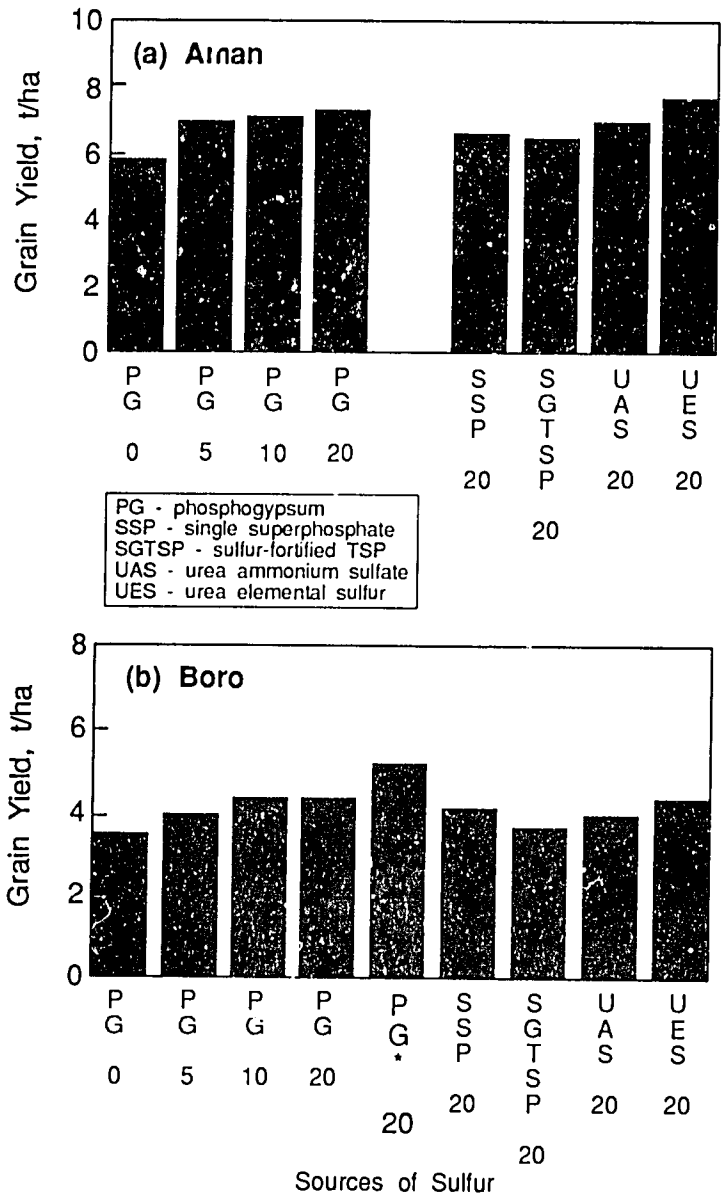
Figure 9. Effect of weed residue recycled to the soil on rice yield in the Philippines.



University in Mymensingh to evaluate alternative sources of sulfur for rice and, using tracers, to estimate the fate of applied sulfur.

Fertilizer sulfur increased rice grain yields by an average of 20% in the Aman season and by as much as 47% (residual effect) in the Boro season (Figure 10). These increases, equivalent to 1 to 1.5 t/ha of grain, were achieved with phosphogypsum applications of 10-20 kg sulfur per hectare. Except for urea-elemental sulfur, granular sources were marginally poorer both in immediate and residual effectiveness than phosphogypsum. Although tracers showed that very little fertilizer sulfur was leached from this system, substantial amounts were removed in the grain and straw (10-16 kg sulfur per hectare and 5-8 kg sulfur per hectare in the Aman and Boro crops, respectively). The effect of these exports is evident in the poor residual values of the 20 kg sulfur per hectare fertilizer-sulfur applications in the Boro crop (Figure 10). Although fertilizer sulfur requirements could be reduced if rice straws (or animal wastes derived from them) were recycled back onto the paddies since the straw contains only 30%-40% of the exported sulfur, substantial sulfur inputs would still be necessary to sustain yields and maintain the efficiency of other (nitrogen and phosphate) fertilizer inputs.

Figure 10. Flooded rice response to fresh and residual rates of sulfur fertilizer sources in Bangladesh (PG-20* applied in Boro).



Economics and Policy Program

Objectives

This program was established to conduct analyses and research in economics, socioeconomics, and policy at the micro and macro levels. At the micro level, the research focuses on (1) the economic evaluation of sources of plant nutrients and management practices that have potential to increase agricultural productivity on a sustainable basis; (2) the study of socioeconomic constraints to the adoption of improved technology in sources of plant nutrients and management practices; and (3) the study of agricultural production systems in terms of the socioeconomic and policy variables that affect the preferences of farmers for such systems. Areas of work at the macro level are (1) the study of public policies affecting the supply and use of organic and inorganic sources of plant nutrients and the development of fertilizer and agricultural sectors; (2) global fertilizer studies to assess and report on trends in global fertilizer use and production; and (3) development of institutional capacity to conduct policy evaluation and research in developing countries—establishment of fertilizer policy research units in national organizations.

Activities and Results

Microeconomics and Socioeconomic Research

Consistent with the restructuring of IFDC following a matrix format, the program activities in 1991 were conducted mainly as components of multidisciplinary research projects.

As part of the Soil Fertility Restoration Project in West Africa, statistical and microeconomic analyses of farm survey data from Ghana, Togo, and Niger were conducted. This work included assessments of the profitability of fertilizer use options, the impact of fertilizer use on crop production, land productivity, and the employment of farm labor. Constraints to the use of organic and inorganic sources of plant nutrients were evaluated from technical and socioeconomic points of view. A paper entitled "Shifting Cultivation, Population Growth, and the Economic and Environmental Benefits of Fertilizer Use" was prepared using data from Ghana. Some results from this study are summarized here.

Shifting cultivation is often characterized as a sustainable strategy for crop production under the conditions of low population growth and density. As human population grows, one alternative is to bring new land into production, usually at the expense of the environment. A second alternative is to increase the productivity of limited land resources through fertilizer use as a component of intensive agriculture that reduces the need to clear forests and cultivate marginal land.

Cross-sectional farm survey data from the Ashanti region of Ghana were used as a basis to analyze relationships between crop production, shifting cultivation, population growth, and the economic and environmental benefits of fertilizer use.

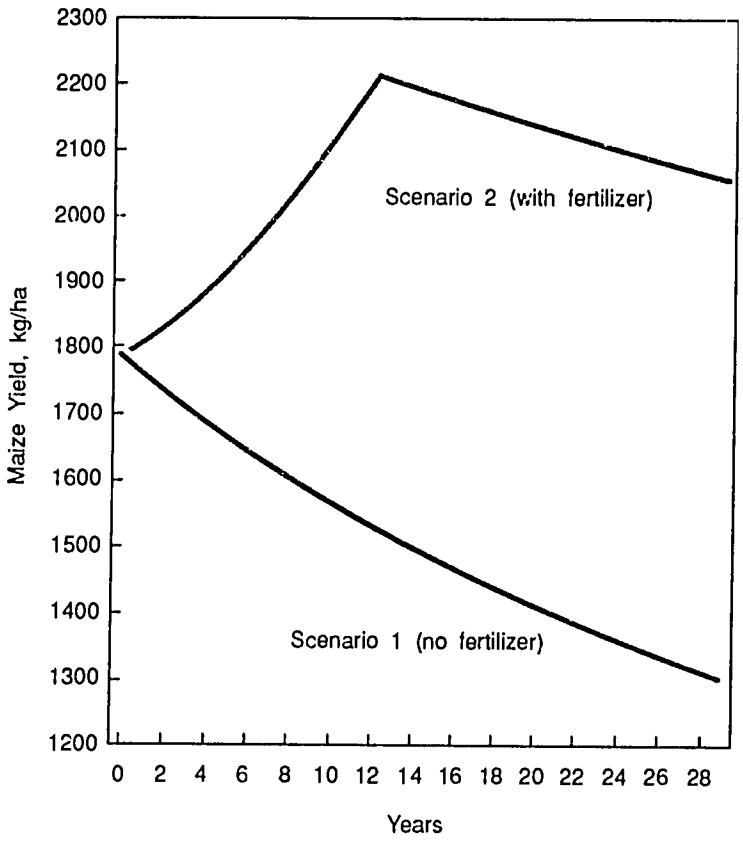
Two scenarios are developed to quantify the economic and social value of the long-term benefits for the environment that result from the conservation of land resources as a consequence of fertilizer use. This benefit is estimated by comparing the projected land productivity and conservation outcomes associated with the occurrence of two possible but opposite scenarios over a 30-year period.

In Scenario 1 the area cultivated with fertilizer is nil. The total area cultivated increases by 3%/year, and the length of fallow decreases by 3%/year. In this scenario, maize yield declines from 1,786 to 1,296 kg/ha (Figure 11) and per capita maize production from 447 to 327 kg.

In Scenario 2 the area cultivated with fertilizer increases by 6%/year, the total area cultivated increases by 1.5%/year, and the length of fallow decreases by 1.5%/year. In this scenario, maize yield increases from 1,786 kg/h to a maximum of 2,209 kg/ha in the twelfth year when the total area cultivated is fertilized (Figure 11). In this scenario, maize yield is increased and sustained at over 2,000 kg/ha over the 30-year period.

In economic terms, the present value of the net benefits of fertilizer use over 30 years, calculated by comparing Scenario 2 with Scenario 1 and using an annual discount rate of 20%, amounts to US $132,709 for the 12,000 ha of total land area or 1,000 ha of initially cultivated area, which is used as the basis for the calculations.

Figure 11. Long-term impact of fertilizer use on maize yields.



Soil degradation and the loss of soil fertility are the most important detrimental consequences associated with the decline in the length of fallow periods and the lack of fertilizer use. Because fertilizer use can prevent these detrimental consequences, the benefit estimated here is in fact the benefit of fertilizer use for the conservation of the land resource base and long-term productivity. However, the benefits accrue to farmers, consumers, and society in general, i.e., to those benefiting from the increased productivity and conservation of land resources.

It is important to recognize that when land-saving inputs, such as fertilizer, are not adopted, agriculture will be expanded into more fragile environments where problems of soil erosion and degradation are expected to become more severe and will result ultimately in the permanent loss of land resources for agricultural production or as habitats for flora and fauna.

Economics of Fertilizer Products and Use Technologies—Research on the economics of fertilizer products and use technologies that increase the efficiency of nitrogen applied was conducted to assess the potential economic benefits of modifications to urea that increase yield through reduction in nitrogen losses. The results suggest that modified urea would provide highest increments in profit and, therefore, incentives for adoption in environments with high response of the crop to urea-nitrogen, high price of conventional urea, and high losses of urea-nitrogen that can be reduced or eliminated (saved) through the modification of urea. Irrigated or favorable rainfed areas with climatic conditions conducive to high crop productivity would presumably represent such environments. In regions with two cropping seasons per year, such as in irrigated rice-rice systems of tropical Asia, the use of modified urea would be more economical in the season with the higher yield response to nitrogen, assuming that savings of applied nitrogen and prices of fertilizer were similar for both seasons. Modified urea products that increase nitrogen use efficiency and reduce losses are more expensive but provide benefits in terms of increasing productivity and reducing leaching of nitrate to the groundwater.

Macroeconomic and Policy Research

Under the USAID-funded Africa Fertilizer Policy Research Project, the policy analysis and research work has focused on two main activities:

1. Fertilizer Policy Research
2. Institutional Capacity Building

Both of these activities are undertaken in collaboration with the International Food Policy Research Institute (IFPRI) and national researchers in Ghana and Mali.

Fertilizer Policy Research

The fertilizer policy research work in Ghana and Mali is focusing on three broad themes, namely, food security and fertilizer use, agronomic potential of fertilizer use, and the policy environment and fertilizer sector development.

Under the food security and fertilizer use theme, an attempt is being made to assess the role of efficient and environmentally sound fertilizer use in promoting food and nonfood crop production and thereby strengthening each country's comparative advantage in attaining food security. The agronomic potential research is focusing on an estimation of maximum potential that each country has in using fertilizers and on the measurement of the gap between potential and actual fertilizer use. The policy environment research tries to identify policy-related constraints affecting fertilizer use and supply and suggests measures to remove such constraints.

The policy environment research activity has selected policies in several areas to assess the conduciveness of the policy environment for fertilizer sector development. These are macroeconomic policy, pricing and subsidy policy, credit policy, supply policy, organizational policy, environmental policy, and research and extension policy. Under each policy various components having direct and indirect impacts on the fertilizer sector operations are analyzed.

The major findings and recommendations of these studies will form a basis for developing a national fertilizer policy strategy and will be presented to the national policy coordination committee in each country.

Institutional Capacity Building

Distorted and nonconducive policy environments have adversely affected agricultural growth and development in many African countries. Limited institutional capacity for policy formulation and implementation in these countries has further compounded the negative (adverse) impacts of distorted policies on rural income. Hence, to develop and promote national capacity for analysis, formulation, and implementation of policies related to fertilizers, IFDC has initiated work on institutional capacity building in Ghana and Mali.

The Fertilizer Policy Research Groups (FPRGs) have been established in both Ghana and Mali. The FPRG in Ghana was established at the Institute of Statistical, Social, and Economic Research (ISSER), University of Ghana, Lagon, and the FPRG in Mali is located at the Institute d'Economies Rurale (IER), Ministry of Agriculture and the Environment, Government of Mali. The members of these groups are involved in conducting fertilizer policy research, which was mentioned above.

The main objectives of these groups are:

1. Conduct research on policy-related issues affecting fertilizer sector operations.
2. Suggest measures to remove policy-related constraints on fertilizer sector development and operations.
3. Design policies and strategies to promote efficient, equitable, and environmentally sound fertilizer use and supply.
4. Monitor the implementation of policy reforms and suggest corrective actions, if needed.
5. Assist policymakers in having a meaningful dialogue with donors and other international and regional agencies.

Because these groups consist of national researchers, the policy recommendations made by them are expected to have a higher degree of acceptability. Hence, these groups will become the catalyst in internalizing and sustaining policy reforms.

Information Management Systems Program

The Information Management Systems Program provides, analyzes, and interprets information on the effective operation of integrated nutrient supply and use systems. The major areas of focus are modeling and biometric applications. The biometric component deals with fertilizer data collection, evaluation, and management for field experimentation and surveys and its integration into management information systems for activities concerned with nutrient characterization, production, use, and efficiency. The modeling component deals with crop and nutrient modeling, developmental modeling, and sustainability and environmental quality modeling.

IFDC's Modeling Component

Modeling and data analysis are activities of the Information Management Systems Program, whose objective is to provide, analyze, and interpret information for use by researchers and clients at field, farm, regional, and national levels. In recent years, emphases on the environment and sustainability have come to the fore. To cope with such emphases, decisions have to be made at many levels: at the farm level, concerning production practices that make judicious use of the farmer's resource base while minimizing production risk, for example; and at the public policy level, where the socioeconomic environment within which farming is practiced can be manipulated in such a way as to distribute income and access to natural resources equitably, and ensure an adequate food supply for urban and rural populations. Information is the key ingredient of decisionmaking for researchers, extensionists, farmers, policymakers, and agribusinessmen.

In response to this need for information, modeling and data management can have two broad roles:

- The first role concerns speeding up and enhancing the efficiency of the research process. Trial-and-error approaches to solving problems are sometimes slow and inefficient. When change is rapid, so must be the response of decisionmakers. Effective problem solving must make use of all the tools available that can help to enhance the efficiency of the research process. Modeling and data management activities attempt to extrapolate research results to other locations and other agroecosystems, initially to bypass the need for expensive and slow field experimentation, through the use of statistical and simulation models that allow research results and technology packages to be screened for different environments. The most promising of these can then enter field testing in the normal way. The result is that, as the explanatory power of models increases, research findings can be extrapolated through time and space in a more efficient fashion than could be achieved using field experimentation alone.
- The second role involves integrating and collating information for delivery to decisionmakers at all levels of the agricultural sector and demonstrating how information can be used to make timely, relevant, and appropriate choices within the institutions and agencies whose job it is to serve the resource-poor farmer of the developing world. Tools such as models, data bases, and decision support systems serve two purposes: (1) data collection that can lead to the identification of critical knowledge gaps, which may be prioritized for purposes of directing further research; and (2) frameworks for decision support systems that can deliver information in a format for direct application in problem solving. A classification of problems that can be addressed in this way is shown in Table 4 by purpose, level, issue, and agroecosystem. IFDC, in collaboration with a number of institutions worldwide, is actively working on decision support system applications for a number of these problems.

Dr. Gareth Edwards-Jones, Research Fellow, the Scottish Agricultural College, Edinburgh, and Dr. Philip Thornton, IFDC Economist/Systems Modeler, work on an aspect of the whole-farm decisionmaking model for Guatemala.

(Photo by Charles Butler)

Table 4. Classification of case studies for the use of decision support systems

Purpose	by	Level	by	Issue	by	Agroecosystem
Tactical Strategic		Field Farm Regional National Global		Agricultural production Soil fertility Nutrient use efficiency Transference of agricultural technology packages Environmental impacts of fertilizer use Agricultural policy Agricultural business viability Risk reduction Promotion of equitability Long-term variations in climate (Drought, water use) (Pest and disease management) (Land use planning)		Humid rainforest Acid savanna Semiarid tropics Steep lands Wetlands Degraded lands

Crop Simulation Model Development

IFDC's modeling focus involves crop and nutrient modeling (the development and validation of crop simulation models and nutrient dynamics models); developmental modeling, concerned with the general application of crop models to the research, development, and extension processes at diverse levels of integration, with linkages to socioeconomic models, expert systems, and Geographic Information Systems; and sustainability and environmental quality modeling, where long- and short-term impact assessments are made of production practices on productivity and sustainability. This work is beginning to include

methodological research on the development of indices for quantifying sustainability, natural resource use, and environmental quality, particularly as related to organic and inorganic nutrients.

Aroid Modeling

A preliminary version of a dynamic crop growth simulation model for edible aroids (taro and tanier) was constructed and is undergoing testing. Called SUBSTOR-Aroid V1.0 (Simulation of Underground Bulking Storage Organs), the model was constructed from field experiments run in Fiji, Hawaii, and Puerto Rico between 1987 and 1990. The edible aroids are an important staple in the Pacific Islands, the Caribbean, West and North Africa, and Southeast Asia and the Far East. Approximately 6 million tons of the crops is produced annually. Edible aroids provide an abundant store of energy, and a steady supply can be produced throughout the year by manipulating planting and harvesting schedules. It is one of the world's most underutilized crops and has great potential. Current yields are low (1.5 to 6 t/ha). Under ideal conditions, yields of tanier (an upland crop) have reached 40 t/ha, and of the more flexible taro (upland and lowland), yields of 50 to 75 t/ha have been recorded. The model has involved a collaborative effort between IFDC and the Universities of Hawaii and Puerto Rico, the U.S. Department of Agriculture/Agricultural Research Service (USDA/ARS) in Puerto Rico, the University of the South Pacific, and the Ministry of Agriculture, Fiji. A workshop, organized by IFDC and International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT), was held in August at the University of Hawaii to review progress; workshop proceedings are to be published in 1992.

Rice Modeling

Version 2.10 of the CERES-Rice model was assembled, tested, and released during the year. This model is capable of simulating upland and lowland (flooded) rice growth and yield. The model simulates growth, development, and yield of rice, and the turnover of organic matter and crop residues. It is sensitive to a number of the important nitrogen transformations in the soil: mineralization, immobilization, the hydrolysis of urea, nitrification, denitrification, ammonia volatilization, and losses of nitrogen associated with runoff and percolation. The effects of nitrogen deficiency on plant growth and their final expression as a reduction in yield can also be simulated. Data sets from Southeast Asia have been used for model development and testing purposes, and the model is being used for a variety of purposes at IRRI.

Sorghum and Millet Modeling

Various modifications were made to the CERES Sorghum and Millet models to make them more robust, in response to an increasing number of data sets that can be used for testing purposes. These modifications have been primarily concerned with the refinement of the crop growth and development components of the models.

Tanier is one of the tropical root crops that the new aroid crop model focuses on.

(Photo, courtesy USDA-ARS, Tropical Agriculture Research Station, Puerto Rico)

Phosphorus Modeling

Work continued on the development of phosphorus routines that describe the uptake and use of phosphorus by the plant. As for nitrogen, a number of the important soil phosphorus processes can be simulated: absorption and desorption of the phosphorus, organic phosphorus turnover, and the dissolution of rock and fertilizer phosphate. The model also simulates phosphorus uptake and the effects of phosphorus deficiency on photosynthesis, leaf expansion, tillering, senescence, assimilate partitioning, and plant development. Once the phosphorus model has been completed, it will be incorporated in all of the crop models on which IFDC is currently working.

DSSAT Version 3

All of IFDC's model development activities are closely collaborated with those of the IBSNAT Project. IBSNAT plans to release a revised version of their computer software (which incorporates crop models, data bases, and application programs, called the Decision Support System for Agrotechnology Transfer [DSSAT]) in the middle of 1992. IFDC is involved in a substantial portion of this work, including new and revised crop models (those for aroids and the cereals) and a new input/output system for all models. The revised version will have the capability of allowing crop sequences and rotations to be simulated over long periods of time. The long-term effects of cropping sequences on soil nutrient status can then be investigated, an important step in addressing sustainability issues. Work has been done on the development of analytical procedures to compare and contrast biological and economic outputs from such long-term simulations. Input has also been made on improving statistical weather generators, whereby daily weather records are simulated for a location where inadequate records exist for simulation purposes. This has been needed to adequately capture the year-to-year variability that is frequently observed in the tropics, especially with regard to rainfall.

Modeling and GIS Linkages

The field research for a UNDP-funded project, "Research and Training in Fertilizer Technology and Utilization," completed in 1990, was undertaken in collaboration with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), and focused on nitrogen use efficiency in sorghum and pearl millet in the semiarid tropics. Biological simulation models of these crops were refined and validated. Subsequently, the models were linked to a Geographic Information System (GIS) containing spatial soils and weather data for the state of Maharashtra, India. Replicated simulations over 25 years were then carried out for a number of crop management regimes involving various planting dates and fertilizer application rates. Maps were produced to show the varying regional responses to different fertilizer management strategies on the Vertisols and Alfisols of the region, in terms of crop yield and its variability, net

Wan Xia (left), IFDC Systems Modeler/Research Assistant, discusses an exercise in the training program on Computer Simulation for Crop Growth and Management with Elizabeth B. Yambao, Senior Research Assistant, International

(Photo by Charles Butler)

returns for different fertilizer application rates, nitrogen uptake and loss, and nitrogen use efficiency. As an example, Figure 12 shows the effects, on a regional basis, of applying 60 kg of nitrogen fertilizer on the yield of sorghum. The response maps show the mean yield, the standard deviation of yield, and the tenth and ninetieth probability levels of yield, the variability arising as a function of the interaction between different weather seasons, each polygon's soil conditions, and management factors. Figure 13 shows, for the same fertilizer application, maps of net return per hectare, nitrogen loss, nitrogen uptake, and nitrogen efficiency.

These types of analyses can have important implications for government, industry, and the farmer. The maps allow easy visualization of the regions in the state that could benefit most from fertilizer use in terms of kilograms of grain produced per kilogram of fertilizer applied, for example; such information could be used to help allocate scarce resources in an average year. Again, the maps can allow identification of areas within a region where fertilizer use is profitable; if profits are increased only 2 years in 10 in a particular area, for example, adoption of fertilizer in that area is unlikely, other things being equal.

This has been primarily a prototype project to investigate the feasibility of linking crop simulation models with a GIS. The production of maps allows a wealth of information to be presented to decisionmakers concerning regions of high crop response to added nutrients, for example, or areas where crop production is highly variable as a result of weather and soil type. IFDC is continuing a major input to the construction of spatial information systems because their potential usefulness to policymakers and researchers is high.

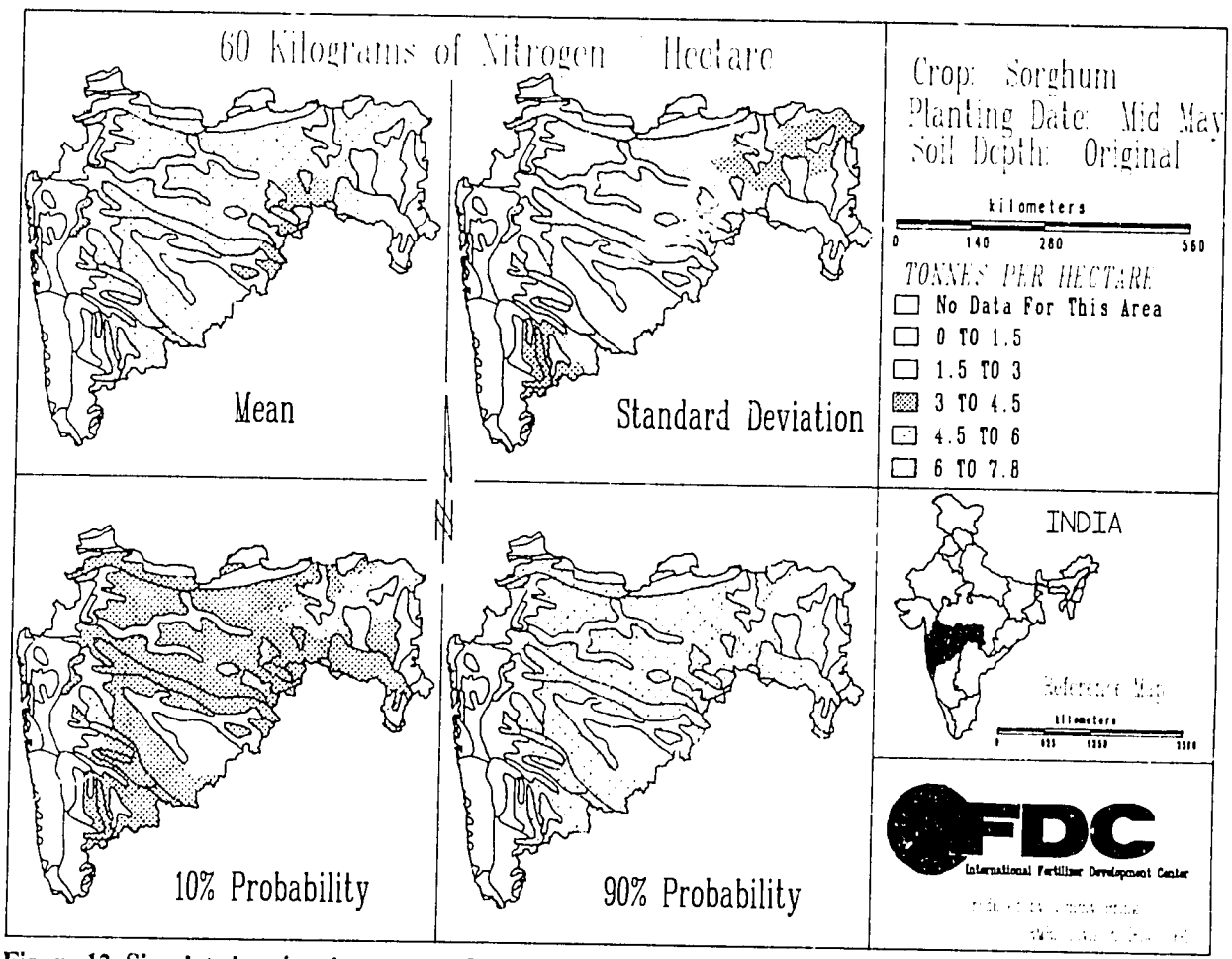


Figure 12. Simulated regional response of sorghum yield to nitrogen application in Maharashtra, India.

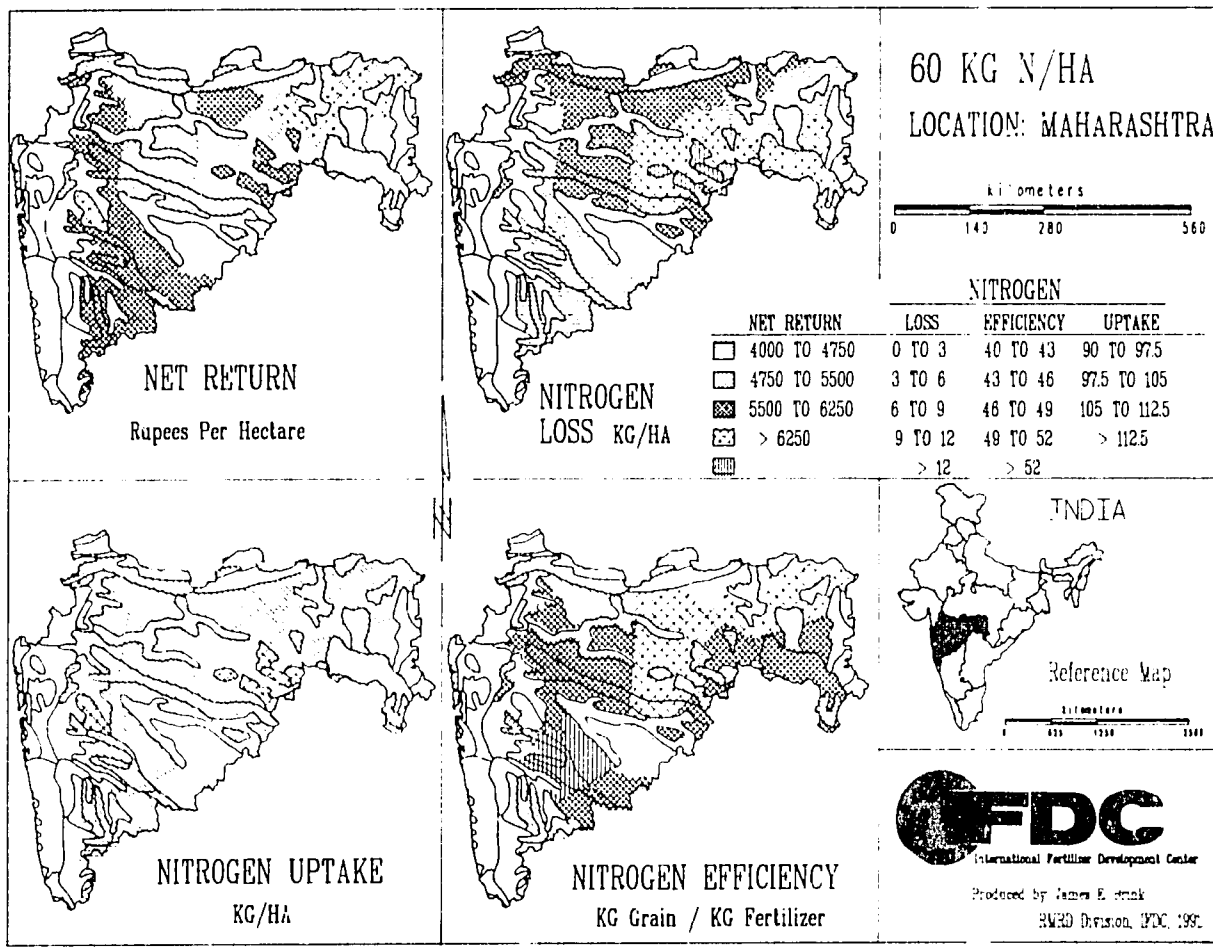


Figure 13. Simulated net return and nitrogen use efficiency of sorghum in Maharashtra, India.

Modeling of Bean-Maize Systems in Guatemala

IFDC continued to have input to an AID-funded project entitled "Biological and Socioeconomic Modeling of Bean-Based Farming Systems in Guatemala." This is a collaborative effort between the Instituto de Ciencia y Tecnología Agrícolas (ICTA); the Universities of Florida, Georgia, and Edinburgh; and IFDC. The objectives are to validate and calibrate crop simulation models of bean, maize, and sorghum and to develop farm-level models of representative farming systems in the southeast of Guatemala. These models are being used to investigate the implications of short-duration bean varieties for traditional farming systems and to help speed the adoption of new technology in low-input systems. To date, field trials have been conducted over four seasons at the experimental station and in farmers' fields in five locations in the region. These data have been used to validate the crop models and to characterize the commonly grown varieties of each crop.

The crop models are in the process of being joined together and form the core of a farm-level model. Socioeconomic data bases are being constructed for representative farms in the region, and these are being linked to rule-based systems that attempt to mimic householders' decisionmaking behavior. Ultimately, it is hoped that such models will play a role in investigating the dynamics of adoption of new technology and in identifying critical bottlenecks and necessary preconditions for the successful uptake of new or improved management strategies.

Maize Modeling in Malawi

The project, "Agrotechnology Transfer Using Biological Modeling in Malawi," is a collaborative effort involving the Department of Agricultural Research, Malawi, IFDC, and the University of

Edinburgh, funded by the Rockefeller Foundation. It involves the validation and application of CERES-Maize, a simulation model for the growth and development of maize, in smallholder production systems in the country. The objectives are to help update fertilizer and crop management recommendations for maize-growing locations in the country, to assemble a broad natural resources data base, and to use the model to help identify priority research areas for increasing smallholder productivity. Field trials are entering their third year at various locations in Central Malawi.

Figure 14 shows a comparison of observed and simulated maize grain yields for four sites in Malawi. The observed yields were obtained from experiments conducted during the 1988/89 and 1989/90 seasons. The simulated yields were obtained from running CERES-Maize with the same conditions as were observed in the field trials: the same daily weather data, soils, and management. Five different varieties were used in these trials, and these were characterized in terms of the parameters needed for running the simulation model. The fit between simulated and observed yields is quite good.

Planting window optimization is critical for minimizing both drought impact due to late planting and crop failures as a result of false starts to the rainy season. For all regions in Malawi, there is a well-defined planting window for maize. Figure 15 shows the simulated planting window for Mwimba, a site characterized by very sandy soils, and two varieties, the local variety commonly grown by farmers in that area, and MH16, a hybrid variety. The gradual decline in yield associated with later planting is due to the increasingly serious effect of water stress on growth and yield; the abrupt changes in yield associated with earlier planting are a result of poor establishment and crop failure resulting from severe water limitations. The actual planting window at Mwimba is somewhat truncated for late planting because late-planted maize is generally more prone to attack by maize streak virus.

For future work, the project will expand site coverage in the country to include all the important maize-growing ecologies. The maize model is being linked to spatial data bases containing information on soils and climate to allow the model to be run for a wide range of conditions.

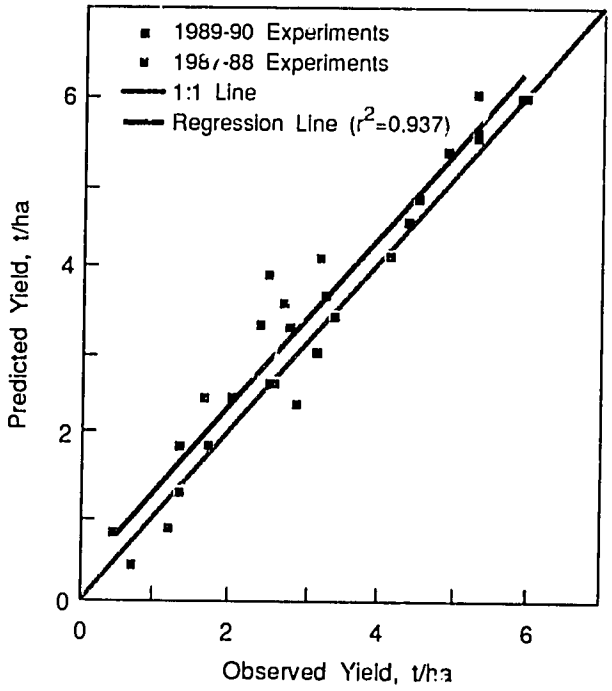


Figure 14. Comparison of observed and simulated grain yields: CERES Maize, Malawi, 1987-90.

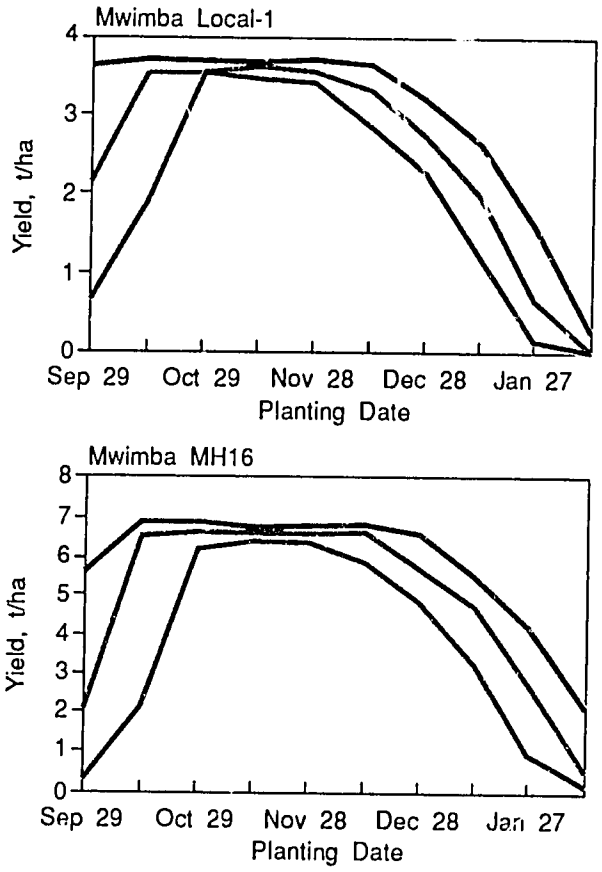


Figure 15. Simulated grain yield response to planting rate as shown by the 10th, 50th, and 90th percentile.

Biometric Unit

The Biometric Unit is a support unit associated with the Information Management Systems Program. This unit conducts research activities and provides services in statistical consulting and data management to research and technical assistance programs conducted by IFDC. A summary of the activities performed during 1991 follows.

Statistical consulting in experimental design and data management for research network activities was carried out by IFDC in West Africa. Assistance was provided to African researchers in the planning and evaluation of agronomic practices and nutrient dynamics for agroenvironments in Mali, Niger, Ghana, Cameroon, and Nigeria. Results of these activities have been published. A data base management system containing experimental results and regional baseline information has been developed and will be useful in supporting fertilizer research activities of the national institutions.

The unit has been directly involved in evaluation and analysis of research results for the project on Fertilizer Investment for Soil Fertility Restoration in Sub-Saharan Africa. This activity involves the estimation and modeling of fertilizer alternatives interacting with organic residues, cropping systems, and farmer management practices in selected regions in Ghana, Togo, and Niger.

The unit is collaborating in areas of statistical modeling in Fertilizer Policy Analysis for Mali and Ghana. This activity is concerned mainly with the use of historical research information to supply a basis for appraisal of agronomic and economic value of fertilizer use and to project agronomic and economic potentials for fertilizer use and crop yields in African environments. This activity has involved the selection and evaluation of research results, model estimation and testing, and geographic analysis for extrapolating results. Preparation of reports on this activity is underway. The Unit also collaborated with Ghanian and Malian researchers and government officers to develop a fertilizer policy support system. This system provides a basis or set of guidelines that may be used to establish a manageable fertilizer data base in African countries. This data base can be used for agricultural planning and can also serve as a basis of information needed in the development and analysis of policies concerning the fertilizer sectors in Ghana and Mali.

Because one of the basic activities of IFDC in developing countries is training, the Unit has been heavily involved in different training activities concerning the use of experimental statistics, data management, and information systems use and development. The Unit organized a formal training course on Agroeconomic Evaluation for Developing Fertilizer Recommendations and provided training on the use of software to researchers of national institutions in Africa, Asia, and Latin America.

Environmental Assessment Program

The Environmental Assessment Program studies and assesses the systems for production and use of plant nutrients to ensure that food production and environmental protection are attainable and sustainable. Maximum protection must be afforded to the earth's air, water, and soil resources to ensure productivity for future generations while at the same time producing food and fiber for an ever-growing population.

Program activities in 1991 centered around an examination of the global phosphate industry to (1) determine its impact upon the environment and (2) estimate the costs required to mitigate any actual or perceived impacts. To this end, a discussion paper entitled "Phosphate Fertilizers and the Environment" was prepared. This paper provided the basis for a case study of the phosphate fertilizer industry that was presented at the October 1991 United Nations Industrial Development Organization (UNIDO) Conference of Ecologically Sustainable Industrial Development held in Copenhagen, Denmark. The discussion paper was also used as the basis for an international workshop organized by IFDC with funding assistance from UNDP. The Workshop will be held in March 1992; the venue will be Tampa, Florida. A second initiative beginning in 1992 will be the preparation of a discussion paper dealing with the impact of environmental legislation on the farm-level availability and cost of fertilizers. This initiative will also lead to an international workshop similar to the one convened to examine phosphate fertilizers.

Regional Focus

East and Southeast Africa

IFDC, through special agreements with the Organization of African Unity (OAU) and by directive from the Center's Board of Directors, has a mandate to develop and direct an overall effort to remove soil fertility and nutrient supply and management as major constraints to increased agricultural productivity in sub-Saharan Africa. In Harare, Zimbabwe, the African Center for Fertilizer Development (ACFD), with an Africa-wide mandate, is initially focusing on the crop production challenges of the SADCC countries and will later include nutrient- and land management-related programs in the eastern region and eventually all of Africa. This Center is essential to focus on the needs of the fertilizer production industry in Africa. ACFD, in collaboration with IFDC and other relevant organizations in the developed countries, can fulfill this role.

ACFD represents an important part of the long-term strategy for implementation of the Lagos Plan of Action for Economic and Social Development, which was adopted by the 1980 Economic Summit of the OAU.

OAU has selected IFDC to serve as the executing agency and provide technical management during the planning, development, implementation, and operation of ACFD initially for a period of 5 years. At its October 1990 meeting, the IFDC Board of Directors proposed that Dr. Samuel C. Muchena, the former Deputy Secretary, Professional, and Technical Services, Ministry of Lands, Agriculture, and Rural Resettlement, Zimbabwe, serve as ACFD's first Managing Director. His appointment was approved by the ACFD Board of Directors.

ACFD's goals and planned programs generally parallel those of IFDC and deal with problems of the total fertilizer sector including fertilizer resource evaluation, production, marketing, and use. In planning its programs initial emphasis is on the Southern African Development Coordinating Conference (SADCC) countries, but expansion to other countries of the region is planned as resources permit. A 5-year workplan and budget has been developed and distributed to donors and other collaborators.

The Workplan identifies programs for research and development on Land Resource Management, Policy Analysis, Resource Development and Utilization, Marketing Services, Human Resource Development, Information Services, and Engineering Advisory Services.

Staffing of ACFD will be patterned after IFDC and include engineers, economists, geologists, marketing specialists, training coordinator, biometrician, crop modeler, data management specialist, holistic resource management specialist, soil scientists, crop specialist, organic resource specialist, donor liaison officer, and program project officer. The crop specialist is already in place.

The crop specialist has already initiated some research activity on the development of methodology for screening mineral use efficiency in cereal crops. This work is being conducted in cooperation with the International Maize and Wheat Improvement Center (CIMMYT) Regional Program based in Harare.

In the area of micronutrient research, the crop specialist has initiated a research project in collaboration with SADCC networks for Food Security and Agricultural Research and an Australian scientist. The purpose of the project is to assess the status of micronutrients in soils of the SADCC Region and establish a data base. The research will also screen for potential sources of genes for mineral nutrient deficiency or excess tolerance on the major crops grown in Africa. A collaborative project between ACFD and the Centre de Cooperation International en Recherche Agronomique pour le Developpement on Optimization of Fertilization in relation to pedoclimatic conditions has also been initiated. A project proposal has already been submitted to the European Community to seek funding for this work.

ACFD is temporarily operating from rented accommodations, but plans are well underway to construct its own offices, laboratories for soil and plant analysis, training center, and a small library.

West Africa

Fertilizer Marketing Research

Primary reasons for the low level of fertilizer use in sub-Saharan Africa (8 kg of nutrients/ha under cultivation on average) include a certain number of shortcomings in the fertilizer marketing system. Some of these reasons are (1) delayed arrival of fertilizer in the consumption areas, (2) lack of credit lines for the purchase of fertilizers by the farmers, and (3) inadequacy of the marketing systems leading to excessive fertilizer prices (in particular in countries where fertilizer subsidies have been abandoned).

All of these problems are generally linked to a development policy and to the government control over fertilizer importing and distributing organizations. Consequently, any action aiming at improving fertilizer use in this part of the world must address these structural deficiencies.

In 1987 IFDC-Africa established Africa's first ever Fertilizer Trade and Marketing Information Network (AFTMIN) with funding from the Netherlands Development Cooperation. In 1991 the project started its second phase for another 3 years and reoriented its activities toward the development of the West African fertilizer market. Its long-term objectives are (1) to intensify the use of plant nutrients in sub-Saharan Africa, as a necessary condition to increase food security and limit further soil degradation through ongoing soil nutrient mining and (2) to strengthen the national capacity with respect to the procurement, marketing, and use of plant nutrients.

Three primary activities to attain these objectives are (1) strengthening the collection, exchange, and dissemination of fertilizer-related information within the AFTMIN countries; (2) conducting comprehensive country/thematic studies in close collaboration with national counterparts, including the identification of concrete follow-up activities; and (3) development of the IFDC-Africa Fertilizer Information Data Base (IFDC-AFID), including establishment of in-country fertilizer support systems.

Regional Services: AFTMIN + IFDC-AFID

A monthly bulletin, entitled "African Fertilizer Market," containing current information on international fertilizer marketing and short articles in English and French, was mailed in 1991 to 319 officials throughout Africa. A monthly overview of the world fertilizer situation with special reference to Africa was sent by fax or telex to 45 correspondents.

Each year IFDC-Africa organizes a meeting of the AFTMIN network to discuss a relevant topic selected by the AFTMIN country representatives. Proceedings of the third annual meeting, AFTMIN 3, on "Fertilizer Demand and Supply Forecasting" are available in English and French.

During the Fourth Annual AFTMIN meeting, AFTMIN 4, 51 participants from 16 sub-Saharan African and 5 European countries met to exchange

K. Abalo, the Togolese SFRP Collaborator, and Dr. Uzo Mokwunye, Director of IFDC-Africa, speak to a group of Togolese farmers who are participating in the SFRP project.

(Photo by Dr.Thomas P. Thompson)

ideas and discuss the theme of the meeting, fertilizer promotion, and sales techniques in Africa. Two Togolese farmers related their experiences with extension services and fertilizer use promotion. AFTMIN correspondents from Benin, Burkina Faso, Cameroon, Côte d'Ivoire, Ethiopia, Ghana, Kenya, Mali, Nigeria, Rwanda, Senegal, Sudan, Togo, Zambia, and Zimbabwe presented their experiences in fertilizer promotion and sales techniques. In addition to network members from African countries, representatives from international organizations such as the Food and Agriculture Organization of the United Nations (FAO), and Care-International, as well as several fertilizer manufacturers/traders shared their experiences with the group. A theme was chosen for the next annual meeting.

National fertilizer statistics for 1990/91 were collected from almost all the AFTMIN correspondents and entered in the IFDC-Africa Fertilizer Information Data Base (IFDC-AFID). IFDC-AFID provides important information on fertilizer supply and demand, types of products used, and economic values such as prices, distribution costs, and subsidy rates.

The data base serves many useful purposes. The collection, analysis, and dissemination of information prior to procurement will be an important use of the data base to discourage excessive procurement specifications, harmonize fertilizer product formulas, stimulate group orders, and achieve timely delivery.

IFDC researchers supported other organizations with regard to the development of the sub-Saharan fertilizer market. They participated in international conferences (e.g., Regional Fertilizer Conference for sub-Saharan Africa, organized by the International Fertilizer Association); national seminars (e.g., Madagascar Fertilizer Marketing Seminar organized by FAO/Madagascar); and a training program on import management, organized by the Program for Development Cooperation of Finland and KEMIRA.

Country Studies and Followup

Studies were undertaken in the first phase of the project on food production and fertilizer use situation in several countries. Studies on Benin, Togo, and Burkina Faso were completed, and the Niger country study was begun. As a result of recommendations made following each study, some developments have occurred in the different countries.

Togo: Followup

Several national organizations and donors (e.g., EEC) have expressed interest in the use of Togolese rock phosphate. In response, a preliminary project proposal was prepared for the distribution and use of rock phosphate in Togolese agriculture, involving three major components: agronomy, marketing, and environmental impact. It is expected that the Government of Togo will request IFDC's assistance for an initial study and evaluation phase for 3 years.

Burkina Faso: Followup

During 1991 the study, "Demande, Approvisionnement et Commercialisation des Engrais au Burkina Faso," was published in French, with an English summary and recommendations.

The Burkina Faso study has resulted in two major activities: implementation of a training program and followup missions to improve operating efficiency of the future National Inputs Secretariat; and a study on the feasibility of fertilizer production in Burkina Faso. Centre de Cooperation International en Recherche Agronomique pour le Developpement (CIRAD) assisted IFDC on the feasibility study. These activities were funded by the World Bank.

Niger

Major policy changes have occurred in Niger since the last study on the fertilizer sector appeared in 1986. Niger opted for liberalization with regard to the marketing of agricultural products (except rice). For supply of inputs, the "Centre d'Approvisionnements" appears to be the main channel for the distribution of fertilizers obtained through international aid at reduced prices. Another phenomenon is the total disappearance of agricultural credit provided by the government.

One of the consequences of the liberalization policy is an increased import of agricultural inputs from Nigeria, and simultaneously an increased export of food crops from Niger to Nigeria. This situation is now quite profitable for Niger but may create problems if Nigeria reduces fertilizer subsidies and intensifies border control. Since traditionally the volume of "parallel" fertilizer trade has

never appeared in the official statistics, it has not been possible to determine the extent of Niger's dependency. The study indicated a heavy reliance on Nigeria for imported fertilizer, which may influence future marketing decisions.

In-Country Regional-Level Data Bases

The development and installation of the "in-country regional level policy data bases" in Ghana and Mali are outputs from interdisciplinary cooperation between the Marketing Project and the Fertilizer Policy Project.

The in-country regional level policy data base contains the following modules: fertilizer nutrient and product statistics, fertilizer pricing and marketing indicators, fertilizer recommendations and management, crop statistics and soil nutrient balance, natural resources and agricultural development indicators, socioeconomic indicators, population, nutrition and demographic indicators, and a library module to store the referenced documentation.

Fertilizer Policy Research

Work continued on the establishment of policies to facilitate the adoption of fertilizers and complementary inputs in sub-Saharan Africa, which was begun in 1987. In 1991 it was realized that dispersion of the research effort over such a vastly diverse geographical region as sub-Saharan Africa would not make a visible impact in any single country. Thus, rather than examine the selected fertilizer sector related issues that prevailed in the numerous and diverse countries in the sub-Saharan region, it was deemed more productive to proceed with fertilizer policy research work by focusing on a few selected countries where real impact could be made. Consequently, Ghana, Malawi, and Mali were selected as impact countries for fertilizer policy research on selected fertilizer-sector related issues coupled with institution and capacity building work.

The goal is to enable the three countries to undertake ongoing analysis of fertilizer and other agricultural inputs policies and to provide timely and accurate advice for policymakers and governments.

Institution and Capacity Building

The project is focusing on capacity building and fertilizer policy research in an integrated way. Fertilizer Policy Units have been established in Ghana and Mali. Fertilizer policy research is done in collaboration with the members of the fertilizer policy units. This approach helps in strengthening and building analytical capacity in the country.

Significant progress has been made in institution and capacity building in Ghana and Mali. The Fertilizer Policy Research Group in Ghana is located at the Institute of Statistical, Social and Economic Research, University of Ghana, and that in Mali is located at the Institut d'Economic Rurale, Ministry of Agriculture, Livestock, and the Environment. These groups function within relevant ministries or have close or direct access to governmental units with responsibility for high-level policymaking.

Policy Research

The research agenda for the Fertilizer Policy Research Project is organized around five main policy issues, namely, (1) Food Security and Fertilizer Use; (2) Agronomic Potential of Fertilizer Use; (3) Agroeconomic Potential and Constraints on Fertilizer Use and Supply; (4) Policy Environment and Fertilizer Sector Development; and (5) Fertilizer Supply, Marketing and Distribution Strategy. The issues that are currently being studied in each impact country were agreed upon unanimously after detailed discussions with national counterparts. Accomplishments to date include: (1) trained national personnel in fertilizer data and information management and analysis, (2) policy reports for Ghana, Mali, and Malawi, and (3) research experience gained by three university students at the University of Benin in Togo as a basis for their Master's theses.

In addition to the research issues listed above, special studies are also underway in Togo and Cameroon. The Togo study focuses on the identification of the key factors affecting farmers' decisions to spend a portion of their cash income from farm and nonfarm sources on purchased farm inputs including fertilizers, high-yielding varieties, pesticides, hired labor, and improved equipment. This study is based on a survey of 96 rural house-

holds in the Haho Prefecture of the Plateau Region in Togo. The research findings will support recommendations for policies to alter the pattern of household cash income allocation in favor of fertilizers and other agricultural productivity-enhancing inputs. The Cameroon study attempts to identify constraints to privatization of fertilizer imports and marketing and make policy recommendations to remove such constraints.

Soil Fertility Restoration Project

Work continued on the project to assess, under contrasting socioeconomic conditions in West Africa, the impacts of fertilizers and animal manures on (1) restoration and maintenance of soil fertility, (2) food and cash crop production, (3) evolution in land use and farming systems, (4) the socioeconomy of village communities, and (5) the implications for reversal of environmental degradation. The project is being conducted in pilot areas in the humid zone of Ghana, savanna zone of Togo, and sahel zone of Niger. Each pilot area consists of 4-5 villages within a radius of 40-50 km of large towns. Two of these villages are designated, respectively, experimental and control villages. A number of variables being studied and a summary of results are given below.

Effects of Fertilizer/Farmyard Manure Use on Crops, Soils, and Water Quality

An important component is to compare the agronomic and economic effectiveness of fertilizer types and socioeconomic effects of fertilizer use in the pilot areas.

Kumasi Pilot Area, Ghana

Average relative agronomic effectiveness in the pilot area of TSP, partially acidulated 50% Togo phosphate rock (PAPR 50), and sulfur-fortified triple superphosphate (TSPS) was, respectively, 91, 93 and 98 on the basis of SSP = 100. This suggests savings in transport and storage costs by using high-analysis materials.

The evaluation of fertilizer option packages actually used or recommended provided the following information: highest maize yields of 3,700 kg/ha resulted from use of 80:40:40 kg/ha ($N:P_2O_5:K_2O$) applied as 15:15:15 compound fertilizer plus urea. However, there were no significant differences in grain yields of Dobidi maize variety by using either of the following packages at 80:40:40 kg/ha: (1) 15:15:15 plus urea, (2) Togo PAPR-50 plus urea plus KCl, and (3) SSP plus urea. Average maize grain yields on the fertilized (package) and check plots in the experimental village were 3,400 and 1,800 kg/ha, respectively. Maize yields from a sample of farmers in the control village averaged 2,200 kg/ha.

Nutrient removal by maize from unfertilized plots over one growing season was as follows: 26.2 kg N, 7.0 kg P_2O_5, 23.7 kg K_2O, 5.3 kg CaO, and 8.93 kg MgO/ha. This phenomenon, which in popular literature is referred to as "nutrient mining," is leading to soil degradation at an alarming rate. Thus, maize grain yield variability in the pilot area was associated mainly with changes in phosphorus rates, plant populations, and age of the bush fallow.

Dapaong Pilot Area, Togo

Average relative agronomic effectiveness of TSP, TSPS, and PAPR 50 in the Dapaong pilot area was 78%, 96%, and 100%. Thus, the material resulting from the lower cost processing of indigenous phosphate rock from Togo into PAPR -50 performed very well. Millet and sorghum yield variability was associated with changes in plant population and fertilization.

Total grain yield of intercropped 3-month millet and 6-month millet ranged from 800 kg/ha on unfertilized plots in the experimental village and 1,100 kg/ha in the control village to 2,500 kg/ha on plots receiving the option 60:35:35 in the form of 15:15:15 plus urea.

Fertilization increased crop biomass above and below ground level. At least 25% of the crop biomass was in the form of roots that helped to improve soil organic matter content and reduce erosion.

The following soil nutrient removals per hectare were estimated from unfertilized plots of the millet/sorghum intercrop: nitrogen, from 6.4 to 12.4 kg; phosphorus, from 1.8 to 3.9 kg P_2O_5; potassium, 45 kg K_2O; calcium, 8.1 kg CaO; and magnesium, 3.8 kg MgO.

Maradi Pilot Area, Niger

Indigenous Tahoua phosphate rock (TPR), TSP, and TSPS had average relative agronomic effectiveness on millet of 63%, 85%, and 92% in the Maradi pilot area. This suggests a role for high-analysis phosphate fertilizers in landlocked Niger. The effect of phosphorus source was independent of method of phosphate fertilizer application.

Bray P_1 soil tests indicated that fertilization with SSP at 60 kg P_2O_5/ha raised phosphorus fertility levels on fertilized plots from 2.6 to 7.5 mg/kg soil. Thus, one of the primary objectives of the SFRP was being met.

For the millet/cowpea intercrop, the highest average millet grain and straw yields of 744 and 1,808 kg/ha, respectively, were obtained from the fertilizer option package 30:60:0 as SSP and urea. This compared with 251 kg/ha of millet grain and 808 kg/ha of straw obtained from the check plot in the experimental village. Average millet grain yield in the control village was 495 kg/ha. Cowpea grain yields were very low in all options because crop damage by pests limited yields.

In the absence of fertilizers, millet removed from the soil 12.4 kg N, 2.5 kg P_2O_5, 18.5 kg K_2O, 3.1 kg CaO, 4.2 kg MgO, and 2.8 kg S per hectare.

Thus, for each zone studied, it was clear that the options boosted crop yields, had a demonstrable effect in the pilot villages, and ensured that fertilizer nutrients supplemented the native soil supply. Farmyard manures at high rates of application also raised crop yields. There were no differences between 1989 and 1990 in nitrate content of well water. Fertilizer use therefore did not result in an increase in nitrate levels of well water. It was concluded that a practice of little or no use of fertilizers in all three pilot areas will lead to further degradation of the soil resource base.

Economic Analysis of Fertilizer Option Packages

Four fertilizer investment options expressed as $N:P_2O_5:K_2O$ per hectare were tested on maize in the Kumasi pilot area of the Soil Fertility Restoration Project (SFRP) in Ghana; namely, 80:40:40 as urea and 15:15:15 (option 1); 80:40:40 as urea, PAPR-50, and KCl (option 2); 80:40:0 as urea and SSP (option 3); and 45:19:19, the extension recommendation as 15:15:15 and ammonium sulfate (option 4).

The results indicate that option No. 4 gave the highest average economic return at harvest even though the increment in yield was low. This is because the cost of this option was about one-half the cost of the other options.

Farmers may increase the gross benefit by storing grain for some time and selling it at an average price of ¢67/kg (US $0.23) instead of between ¢22 and ¢34/kg (US $0.07 and US $0.13, respectively) obtainable at harvest. This will, however, entail additional costs including storage, handling, and losses during storage.

The value:cost ratio after storage was higher than 3 for all the options tested except option No. 2. Option No. 4 gave the highest average economic return to investment. Although option No. 3 allowed farmers to earn more money, the risk element in this option was high and the return to investment was low.

The value:cost ratio distribution after storage indicated that 95% of farmers who used option No. 3 and 81% of those who used option No. 4 attained a minimum value:cost ratio of 2.

Regarding net benefit distribution, farmers who used option No. 3 earned about ¢35,000/ha (US $120.69) compared with ¢15,000/ha (US $51.72) for those who used option No. 4. In summary, option No. 3 was the best of all the four investment options if farmers decided to store production, but this will require a substantial cash investment. The advantages of option No. 4 were that it yielded the highest average economic return at harvest, and the risk element involved was low after storage.

Fertilizer/Manure Use, Food Security, and Cropping Systems

Detailed surveys were conducted on the use of mineral fertilizers and animal manure and on household food consumption in 1989 and 1990 at Tchizon village, Niger. 1989 was a very good year in which farmers built up food stocks for household consumption. 1990 was a year of surplus production. The major production was millet and sorghum for food, tiger nut for cash, and cowpea and peanut for both food and cash. A fertilizer bank, created by the SFRP project and stocked mainly with SSP and urea, tripled the number of fertilizer users (increasing from 33% to 98% of farmers). Three quarters of

farmers used animal manures on one-quarter of the cropped land. In 1989 manure and fertilizers were almost exclusively used on collective plots managed by men (99.7% and 94.4%, respectively), but after food self-sufficiency was attained, fertilizer use decreased in 1990 to 72.9% because of the cultivation of individual plots and the activities of women. Fertilizers were always used on plots nearest dwellings. Ninety percent of manure and 73% of fertilizers were used within a 2-km radius of the village.

Fertilizers were used mainly on crop associations (70%). Most fertilizers were used on food crops (73%) until farmers met their food needs, and then the quantity decreased to 56%. Farmers used manures, which involved only labor costs almost exclusively on food crops (93%) and mostly on legume-based associations (62%). Mineral fertilizers, which cost money, were used more on cash crops (44%) and legume associations (16%).

The surveys demonstrated that almost everyone was a fertilizer user when economic circumstances were good. A major concern of research in the future should be to improve techniques of fertilizer use in crop associations.

Variations in Farmer Perceptions About Fertilizer Use

Means of restoring soil fertility by using mineral fertilizers were studied by socioeconomic surveys. Two ecological zones in West Africa were considered: the Sahelian area in South Niger and the Savanna in northern Togo. The study was done on two villages with degraded soils in each ecology: Tchizon and Maiguero in Niger and Naki-Est and Kpembona in Togo. Farmers' perceptions about mineral fertilizer were evaluated by two different methods: (1) opinion surveys and (2) the study of the functioning of farmer groups created by classifying them according to their ability to use fertilizers. The results fr the two methodologies emphasized possibilities of estimating the demand for fertilizers on the basis of groups of farm characteristics. Variables to define groups, identified by multidimensional statistics, differ for each country. In Togo animal traction and number of workers in the family were the two most important parameters. In Niger where land area is less restrictive, area per worker and workdays per hectare were important. The typology emphasized the variability of farmers' capacity to solve the problem of soil fertility management. It facilitated the targeting of extension advice taking into account a variety of needs, demands, and capacity to use fertilizers. The next step will be to extend the typology using an exhaustive farm census data base and to work on a plot typology focused on the same problem of the capacity to manage soil fertility.

Impacts of SFRP Activities on Users and Nonusers of Fertilizers

Central to the socioeconomic studies of the SFRP is a longitudinal survey of a panel of 60 farmers from each of the six research villages in the three pilot areas. The objective of this annual activity is to generate a broad range of socioeconomic data to monitor and evaluate the qualitative and quantitative impacts of SFRP activities on users and nonusers of fertilizers. The third in the series of surveys was completed in 1991, and the data are being analyzed. It involved a total of 370 farmers, including 133 women.

Preliminary results from analyses of the 1990 survey data from Niger indicate that, in a relatively short span of 2 years (1988-90):

1. Food production and farmer incomes among users of fertilizers increased about twofold while those of nonusers, at best, stayed the same.
2. Fertilizer use resulted in additional employment of farm labor at a rate of 16 workdays per hectare of cropland.
3. The average plot area among users of fertilizers reduced by 0.82 ha compared to only 0.25 ha among nonusers. This suggests that the use of fertilizers is gradually facilitating investments in land conservation measures that enhance the preservation of the environment.
4. On the average, users of fertilizers, compared to nonusers, have significantly added to their capital stock in the form of grain, equipment and handtools, and farm animals.
5. Among women collaborators, users of fertilizers are gradually diversifying into the production of "new" cash crops, in particular tiger nuts, to increase their incomes.

6. Farmers who used fertilizers, compared to nonusers, perceived significantly more improvement in their socioeconomic well-being.
7. At the village level, users of fertilizers constructed a 3-km access road and a market through communal labor and voluntary contributions; the two projects have greatly enhanced the delivery of fertilizer and other inputs, while minimizing the cost of marketing farm produce.

Labor Contributions of Men and Women to Crop Production Activities

Farm survey data were used to examine several hypotheses about labor contributions of men and women to crop production activities in the pilot areas. No conclusive evidence was found for the generalization that agricultural work south of the Sahara is dominated by women.

Agricultural labor appears to be based on negotiation and exchange rather than on gender per se, and a naturalistic view of a division of labor in sub-Saharan Africa based solely on gender appears fallacious and generalization on that subject weak. Instead there is labor reciprocity between men and women, the nature, terms, and dynamics of which require further research.

Human Resource and Institution Building

a. Training of Collaborating National Staff

Human resource development remains an integral part of the goals of the SFRP. A combined total of 134 national research and extension collaborators benefited from 15 general and 9 individualized training programs conducted by IFDC-Africa scientists at the three locations of the SFRP and at Lomé.

Using a variety of methods including workshops/group discussions, case studies, lectures, role-play, and field demonstrations, IFDC-Africa scientists provided training in the following areas: workplan and budget preparation, design and field layout of trials and option package plots, soil and plant sampling, soil characterization, methods of fertilizer application, the conduct of socioeconomic surveys, data processing and interpretation, extension communication methods and practice, and census surveys.

b. Training of Farmers

Training at this level in all locations of the SFRP was organized and supervised by national collaborators with occasional back-stopping from IFDC-Africa scientists. The objective was to demonstrate to farmers the use of recommended technologies and cultural practices.

Through group meetings and field days, approximately 800 farmers have acquired skills in fertilizer handling, application and storage; the use and storage of improved seeds; and post-harvest crop management.

c. Institution Building

Three farmer associations and fertilizer revolving funds have been established in the SFRP experimental villages in Ghana, Togo and Niger. The long-term goal is to create a dependable source of funding for fertilizer and soil amendment use on a sustainable basis in the pilot areas.

As a village-level activity, the process of disbursement and reimbursement to the fund has been organized by farmers under the management of a popularly elected committee. Liaison services are provided by the in-country coordinator who also serves as a technical advisor to the management committee. The project is closely monitoring the activities of the farmers' association and the operation of the funds through the annual surveys.

Agronomic Research: Fertilizers and Sustainable Agriculture

Evidence is accumulating that the single most important factor limiting crop yields in West Africa is low fertility due, in part, to natural soil infertility and/or the very low levels of fertilization to replace nutrients removed by crops. Low levels of organic matter, total nitrogen, total and available phosphorus, and effective cation exchange capacity characterize West African soils.

The immediate objective of the UNDP-funded agronomic research project is to arrest soil degradation by promoting higher and more efficient use of fertilizers to increase food production in West Africa. The project aims, through collaboration with national research and extension systems, to develop information on the fertility status of the soils, the amounts of fertilizers to apply to crops, the economic sources of fertilizers to be used with emphasis on fertilizers produced with indigenous

Table 5. Effect of different fertilizer combinations and organic amendments on maize yield at different sites in Togo, 1991

Treatments	Davie		Amoutchou		Kaboli		Agbassa		Koukombo	
	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover
	(kg/ha)		(kg/ha)		(kg/ha)		(kg/ha)		(kg/ha)	
1. Control	1685	2873	1586	1805	1922	2978	800	1927	1286	1458
2. P(TSP)[a]+N+K	3600	4461	3537	3469	3800	5300	2400	3903	4113	5366
3. N+K	2800	4230	2330	2630	1989	3222	1927	3115	2676	3479
4. P(SSP)[b] +K	2109	3115	2134	2538	3522	5267	497	1430	2024	2805
5. P(TSP)+N+Mg+Zn	3515	4460	3396	3854	3955	5278	2642	4533	3698	4484
6. P(SSP) +N	2400	3636	3245	3209	5155	6400	2776	4315	3864	5300
7. P(SSP)+N+K	3818	4752	3565	3509	4256	5478	3974	5939	5136	7421
8. P(SSP)+N+K+lime (L)	3333	4327	3722	3941	4256	6100	3564	6000	5698	78419
9. P(SSP)+N+Mg+Zn	3539	4389	3882	3963	4455	5955	4012	5818	5933	7328
10. Crop residue (CR)	1273	2691	1578	2538	1367	2533	642	1648	1709	2236
11. CR+1/2(N+P+K)	2824	4048	2793	2950	3867	5111	1879	3442	4175	5546
12. Manure (M)	1515	2570	3284	3677	3111	4444	1806	3309	2075	2706
13. P(SSP)+N+P+K+Mg+Zn+L	2921	3939	4224	4320	4878	6155	3891	5964	5108	5983
14. Trt 9 + L	3479	4630	4098	4556	5144	6045	3091	4606	5820	7319
15. Trt 14+M+L	4206	5236	4334	4359	5489	6800	4861	8061	5388	6442
SE	243	241	378	426	454	460	305	443	288	435
C.V., %	19	14	26	28	26	20	26	23	16	19

a. TSP = triple superphosphate
N rate: 90 kg N/ha.
P rate: 24.6 kg P/ha.
K rate: 50 kg K/ha.
Mg rate: 20 kg Mg/ha.
Manure rate: 10 t/ha.

b. SSP = single superphosphate.
Zn rate: 10 kg Zn/ha.
CR rate 3 t/ha.
L: lime applied every 3 years, 500 kg/ha.
For treatment 11, one-half of the N, P, and K fertilizer was applied.

materials, and the best management practices to ensure a healthy environment for sustainable agricultural production.

The 1991 crop season was a good one from the point of view of rainfall distribution although some countries such as The Gambia and Senegal suffered from periodic droughts. Trials at IFDC-Africa (IFDC-A) benchmark sites in Togo (5) and in Niger (4) and at the 14-nation West African Fertilizer Management and Evaluation Network (WAFMEN) sites were carried out with success. Those field trials continue to assess plant nutrient needs, the effectiveness of different fertilizer sources including their residual effects, and the management of soil and water to promote efficient nutrient use and arrest soil degradation (Table 5).

Although phosphorus deficiency is widespread and is a major constraint to crop production in West Africa, moderate amounts of phosphorus amendments are usually required for optimum crop production as a result of the low sorption capacities of the soils. Farmers in the region lack adequate capital for the purchase of commercial phosphate fertilizers, which are imported. However, the data obtained in 1991 suggested strongly that an economic alternative could be the use of local phosphate rock in ground or partially acidulated forms. Calibration studies to demonstrate the cost-effective recommendations for phosphate fertilizers showed that, for the water-soluble phosphate fertilizers, the standard methods such as Bray P1, Bray P2, Mehlich 1, and Olsen could be used interchangeably in assessing phosphorus availability. The phosphorus sufficiency level obtained using Bray P1 was 6.6 mg phosphorus per kilogram for pearl millet in the Sahelian zone and 7.5 and 10.7 mg phosphorus per kilogram for cowpea fodder and sorghum, respectively.

Trials in the Sahelian zone showed that rotating legumes with cereals could limit the amount of, if not eliminate the need for, inorganic fertilizers in the soils. The agronomic data from the on-farm trials in Togo clearly indicated that the use of partially acidulated phosphate rock (50%) could replace the use of imported commercial fertilizers (Figure 16). Organic recycling of crop residue is an important part of integrated plant nutrient management. In the Sudano-Sahelian zone of Mali and Niger, the addition of manure and crop residue was indispensable for sustainable agricultural production.

WAFMEN continues to grow and mature as one of the most active networks in West Africa with more national scientists embarking on on-farm trials. In order to develop national capabilities to collect, analyze, interpret, use, and manage data, a training course will be organized in 1992 on fertilizer data collection and management.

As a result of the work carried out under this project, there is increased donor interest in the establishment of small-scale village-level pilot plants for the production of fertilizers using indigenous resources.

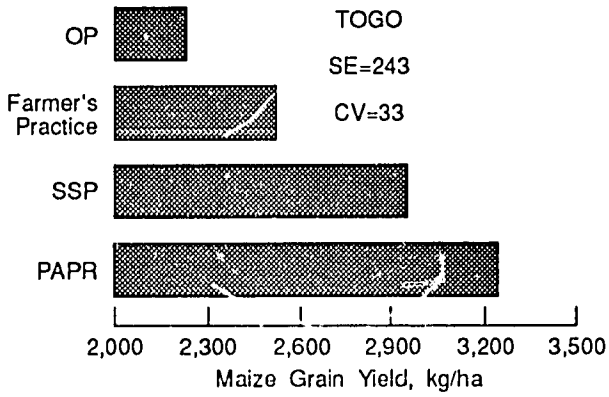


Figure 16. Effects of different P fertilizer sources on maize grain yield in on-farm farmer-managed trials in Togo, 1991.

Asia and Europe

Agribusiness Program

IFDC's new slate of programs includes agribusiness—an effective development tool. This program component focuses on the development of a comprehensive system to support and foster increases in agricultural production. It integrates cost-effective, environmentally sound strategies for supply, marketing, and use of agricultural inputs and outputs with special emphasis on plant nutrients.

Since its beginning, IFDC has been involved in developing improvements in the marketing of plant nutrients. However, the full benefits of these improvements are achieved only when complemented by improved availability of other agricultural inputs and ensured markets for the output. Only then can farmers make the transition from subsistence farming to the market economy. Such a change is needed not only to improve food availability and halt environmental degradation but also to promote sustainable agricultural production systems.

As a sector of the economy agribusiness includes all of the agricultural sector and a significant portion of the industrial sector. Agribusiness is the sum total of all operations involved in the manufacture and distribution of farm supplies; production activities on the farm; and the storage, processing, and distribution of farm commodities and items made from them. Its contribution to the gross national product of developing countries can be tremendous. It can provide the greatest number of employment opportunities.

Agribusiness consists of the following components: farm suppliers, farmers, processors, transporters, financiers, wholesalers, retailers—all of which must be oriented toward the consumers of the market. The facilitators who make the entire system work include government policymakers, company managers, training specialists, and researchers.

In this section IFDC's agribusiness efforts in Albania, Bangladesh, and Indonesia are discussed.

Albania

With financial assistance from USAID, consultants from IFDC visited Albania in October and December to assist the USAID project design team and also to assess the in-country production, supply, distribution, and marketing of fertilizer and other key agricultural inputs for the development of an Agricultural Adjustment Project (AAP) to be funded by USAID.

IFDC consultants observed that the entire Albanian fertilizer and agricultural system was almost at a standstill because of very rapid changes from a completely centralized and rigid "plan" system to a totally deregulated system with the cooperative farms in the process of being distributed to individual small farmers.

Albania had been self-sufficient in fertilizer through 1990, the economic transition was taking its toll, and the central command structure for fertilizer production and distribution systems were faltering. In 1990, Albania produced and used 235,000 tons of fertilizer. In 1991, the IFDC team

The beginnings of free enterprise are taking shape in Albania as evidenced by this farmer's privately operated vegetable stand.

(Photo by Dr. W. E. Clayton)

estimated that only 160,000 tons of fertilizer would be produced and available to in-country distribution with no chance of importation. The domestic supply reduction was a result of "transition," technical breakdown, inadequate feedstocks, and needed spares. As a consequence, 1991 agricultural output fell substantially although accurate estimates were not available in Albania.

The team further reported that Albania faces at least two major domestic problems. One concerns food supply and the other concerns ways and means to develop a free market agricultural sector. The strategies to deal with the food supply crisis have been met by importing food aid to meet demand not provided by Albanian agriculture. A more durable and long-term approach is to increase domestic food production through the use of agricultural inputs, especially fertilizer. The team emphasized that "fertilizer is the critical input to restoring or maintaining agricultural output in Albania." Increasing domestic food

An Albanian farmer and his horse framed against the backdrop of Skanderbeg's Castle in the city of Kruje.

(Photo by Dr. W. E. Clayton)

production through the use of fertilizer is an efficient means of maximizing the benefits of aid and assisting Albania in making a transition from a centralized agricultural system to a free market system.

The IFDC team report strongly recommended that the initial focus (AAP project) for the first 6 months of 1992 should concentrate on supply and distribution of fertilizers using private-sector resources on an emergency basis.

Indonesia

The Indonesian fertilizer industry is undergoing a large expansion in urea capacity involving both new plants and optimization projects on several of the older urea plants. This fertilizer restructuring project, funded by the World Bank, also included two distribution/marketing studies. P.T. PUSRI revised the original 1986 joint IFDC/P.T. PUSRI distribution study and IFDC conducted a new fertilizer marketing study in 1991.

The Indonesia Fertilizer Marketing Study was conducted by a seven-member team in Indonesia from October to December and was complemented by companion marketing reports prepared in Bangladesh, India, Pakistan, and the Philippines. The study objective was to examine alternative marketing systems applicable to Indonesia, which could improve efficiency and reduce costs compared to the current subsidized government monopoly system. A strong emphasis was placed on examining the requirements for the development of an open, competitive marketing system. The report will be completed in early 1992.

Bangladesh

Because of its accomplishments in restructuring its fertilizer marketing system, Bangladesh has emerged as the Asian pioneer, and it can serve as a model for privatization of the fertilizer sector in other developing countries. Several Asian and African developing countries that are undertaking such programs visited the IFDC-Dhaka office to learn lessons and observe the impact of the Government of Bangladesh policy reform accomplishments during the year 1991.

The IFDC-conducted farmer fertilizer use survey report, completed during 1991, indicated that "the benefits of the GOB's policy changes for agriculture and improvements in the inputs supply systems are now shared by small farms including landless tenant farms and those who own less than 2.5 acres of land." These small farms represented 76% of the total farm community, and they had control of almost 50% of the total Rabi/Boro season (1990) crop acreage in Bangladesh.

IFDC's technical assistance consultancy to the Government under the fertilizer projects funded by USAID has policy reform orientation focusing on creating marketing infrastructure for entry of the private sector in all facets of fertilizer marketing. This policy reform activity resulted in a gradual shift from a public-sector distribution system to a free marketing system ensuring nationwide adequate supply and availability at a reduced price. Technical assistance for administration of commercial credit and privatization of fertilizer imports was the highlight of the year's activities.

During the year under review, the technical assistance project concentrated on consolidating the marketing developments and policy changes achieved during the past years and continued developing modalities integrating commercial credit and banking with the private-sector imports to be funded by donor countries including the USAID.

On July 6, 1991, the first private-sector imports broke the public-sector (Bangladesh Agricultural Development Council [BADC]) monopoly, setting a milestone in the history of Bangladesh fertilizer marketing. Although the private sector was completely new in fertilizer imports, its import market share rose to 30% (65,000 t) during the last 6 months of 1991. Their performances, including the discharge and handling of fertilizers from ports to the farm distribution network, proved cost-effective and more efficient than the public sector.

The success of private import inspired the Government and Asian Development Bank to allocate funds of US $34.85 million to further encourage the participation of the private sector in fertilizer imports and to strengthen the Government policy change commitment for a free-market economy in agriculture input marketing.

The integration of fertilizer importation through the private sector with domestic distribution and marketing has further increased availability and competition in fertilizer marketing. Private-sector aggressiveness and the speed with which it enforced the fertilizer market and penetrated the countryside has had a sudden and sharp impact on public (BADC)-sector fertilizer operation. From a total monopoly public-sector national market share dropped to 7% of the total market share.

Fertilizer price is now determined in a truly competitive marketing environment. Intense competitive pressure has forced importers, distributors, dealers, and retailers to economize cost, reduce marketing margins, and provide opportunities for the farmers to receive needed surplus at reasonable prices throughout the year.

IFDC farmer/dealer profile survey analysis indicates that the fertilizer dealers have started rendering a variety of services to their customers, which is a significant component to the success of fertilizer marketing in Bangladesh.

Ensuring availability of credit for fertilizer importers/ distributors to support a strong and competitive private-sector fertilizer market in Bangladesh that will make fertilizer available to farmers year round at the lowest possible cost is an important mission of IFDC's technical assistance to Bangladesh. Substantial credit requirements were envisaged to shift the fertilizer marketing function from the public sector (BADC) to the private-sector importers and distributors. For the large-scale operation of buying fertilizers directly from the factories and ships, a fully commercial credit program was established through the commercial banks under the guidance and supervision of the Bangladesh bank with funding from USAID in late 1989. Since then, the funds are being used extensively by fertilizer distributors. Major commercial banks of Bangladesh are participating in the program. Fourteen banks including five public-sector and nine private-sector banks have been involved in the program and during the year disbursed credit up to TK 873 million to 465 distributors, which is 259% higher than the previous year. The turnover rate of credit use increased during the year to 6.75 as compared with 4.5 in the previous years, indicating a more intensive use of the funds.

Another objective of the credit program is to increase the downward flow of credit from the distributors to subdistributors, dealers, and retailers of fertilizer. To assess the quantum of such credit passover, a survey was carried out that indicates that an average 46% of the distributors' credit passed to subdistributors for a period of 3 weeks and that 33% of the subdistributors passed the credit to retailers for a period of 7 weeks. The credit program has produced a major change in the fertilizer trading pattern. The distributors and dealers who were earlier involved only in cash transactions for buying and selling fertilizer are now truly and extensively available to banking services.

The dealer training and development program continued to receive a high priority because of the important role of dealers in influencing and promoting increased and efficient use of fertilizer.

Outreach

Through its outreach activities—technical assistance, training, workshops, seminars, and other meetings—IFDC reaches its audience of policymakers, scientists, industry personnel, and educators. These activities are conducted by multidisciplinary teams, comprised of IFDC staff, other international and national organizations, and individuals. The various components of the outreach process are discussed in the following sections.

Technical Assistance

A significant portion of IFDC's efforts continues to be devoted to providing technical assistance to governments, industry, and other entities in the developing countries. This assistance may include helping improve, for example, the production capability of a specific fertilizer plant, establishing a free marketing system, or increasing the effectiveness of an existing system, assisting in the development of fertilizer policies, and assisting with institution building and capacity development in such areas as information management.

During 1991 IFDC's technical assistance activities were conducted in 11 countries. On the African continent the Center provided assistance to Algeria, Egypt, and Ghana; in Asia—Bangladesh, Indonesia, Malaysia, and Saudi Arabia; in Latin America—Chile, Colombia, Costa Rica, and Mexico. These activities are discussed in the following sections.

Africa

Algeria

The UNDP-funded Algerian Fertilizer Distribution Project was managed by the World Bank, and Bureau National d'Etude pour le Développement Rural (BNEDER) was appointed by the Ministry of Agriculture as the counterpart agency for the study. The IFDC team was composed of eight specialists in the areas of general and cereal agronomy; horticultural production; fertilizer production, marketing, and use; cooperative development and management; and policy and economic issues.

The goal of the study was to increase crop production through the identification of constraints that could be removed by modification of government policies aimed at improving the supply and distribution of fertilizers and their rational use by farmers.

The objectives of the study were to complement two earlier UNDP projects by strengthening the fertilizer marketing and distribution system in its widest sense—supply, movement and storage, sales and use—through an appraisal of infrastructural, organizational, and policy factors affecting the system.

All of the specialists made in-country appraisal missions. The whole range of crop production systems used in Algeria, particularly as related to the currently recommended fertilizer practices and actual farm practices, were examined. The fertilizer marketing and distribution systems and the role that the private sector and autonomous cooperatives would play were evaluated. The national fertilizer supply systems were appraised in terms of capabilities, management, plans, and investment needs. Finally, the current economic situation was studied in relation to agricultural production potential and its impact on food needs and from the fertilizer industry point of view in terms of its future role and of material supply needs and export markets. The effects of the move to a fully convertible currency on the fertilizer production and agriculture sectors were examined; the reactions to these effects were analyzed.

Key observations that certainly have great relevance to all of the former centrally planned economies are that:

1. The production of the centrally planned state farms, which were on the best agricultural land in Algeria, stagnated despite the fact that they received priority allocation of all the key inputs—fertilizers, pesticides, machinery, etc.
2. The private sector based on small farms showed much dynamism as regards crop diversification in response to market demands.
3. The fertilizer industry suffered from poor policy decisions, which seriously reduced its technical and managerial capabilities.

Previous Page Blank

Recommendations, which are aimed at overcoming the constraints identified and which will help to move the fertilizer sector in the direction of a competitive customer-oriented system, were developed by the study group.

Egypt

Assistance was provided to EFDC in setting up a bench-scale phosphate granulation unit through a contract with UNIDO, serving as executing agency for UNDP. The bench-scale unit, designed by IFDC, will be used by EFDC in establishing a national program for an organized development of the fertilizer industry in Egypt.

The unit was erected by an IFDC team, within the Abu Zaabal Fertilizer and Chemical Company, at Abu Zaabal, with mechanical and electrical assistance from that company, using components purchased by UNIDO from different sources, particularly from IFDC. The personnel assigned to the unit were trained by the IFDC team in the operation of the different components.

Under the direction of the IFDC team, a production run of granular TSP was made to the satisfaction of the Egyptian counterparts. Besides an operations manual, a vast array of technical literature, and a list of required spare parts, a report was issued recommending an organization scheme for the research and operating staff, as well as a research program to be carried out during the next several years.

Ghana

The Government of Ghana is actively pursuing the goal of establishing a market-oriented economy for seed and fertilizers. The Government intends to liquidate all seed and fertilizer assets and liberalize prices, thus eliminating the fertilizer subsidy, which is estimated at about 45%. With financial support from USAID, the Government contracted with IFDC for a study of the potential for privatization of the seed and fertilizer subsectors and to prepare an action plan to facilitate the transition to a market-oriented system.

IFDC determined that the potential for establishing freely open and competitive markets for seeds and fertilizers was favorable. Moreover, it was viewed as essential to reversing the decline that had occurred in both markets during the 1980s. The strategic action plan developed by IFDC called for a total commitment to the privatization effort by the Government. The plan includes four main components as follows:

1. Establishment of a government policy framework that clearly defines the role of the public and private sectors, encourages entrepreneurial investment, promotes competition, and protects national interests.
2. Development of the credit system to accommodate the financial needs of entrepreneurs in the seed and fertilizer business in accordance with acceptable banking practices in Ghana.
3. Transfer of technology (through needs-based, targeted training, and technical assistance) in seed production and marketing, fertilizer procurement, marketing, etc.
4. Development of the institutional structure to support a market economy for seeds and fertilizers.

Acting on the plan, the Government requested that USAID provide additional funds to initiate the technical assistance activities. Accordingly, IFDC assisted with the development of a strategy to promote the orderly liquidation of stocks of the Ghanian Government. The pricing strategy has been implemented, and discussions are now in progress concerning full-scale implementation of the privatization plan.

Asia

Bangladesh

A physical assessment of the Triple Superphosphate Complex Limited was performed by an IFDC engineer during 1991. The assessment covered the damage caused by the April 1991 cyclone and tidal bore, which struck the complex site at Chittagong; the necessary repairs inclusive of time and cost; plant capacity; and possible alternative uses for the complex. The complex was severely damaged by both the high winds of the cyclone and the 4-ft-deep saltwater flood throughout the area caused by the tidal bore.

Within a few weeks the TSP section of the complex was restored to operation using imported acid. The repairs made to effect this quick return to production were of a temporary nature and could only be expected to last a short time. The permanent repairs necessary to return the complex to pre-

storm condition were estimated to cost US $3 million and take about 6-9 months to complete. Details of the repairs needed and their costs along with maintenance costs and expected life of individual plants in the complex were included in a report to USAID. The report was requested by USAID on behalf of the donor nations.

Indonesia

Marketing Study—The "Indonesia Fertilizer Situation and Outlook Report: Focusing on the Farm Level" was a technical assistance project conducted for the Indonesia National Development Planning Agency (BAPPENAS), funded by the Economic Policy Support Office/USAID, Jakarta, Indonesia.

IFDC provided the services of two specialists—a fertilizer marketing specialist and a consulting fertilizer information specialist—to design a reporting format for an annual fertilizer situation and outlook report; develop simple computer software to allow followup reports to be prepared by BAPPENAS on an annual basis; collect the information needed for the year's report, inclusive of a recommended increase in fertilizer retail prices for 1991/92 that will not adversely affect farmers' income; and train BAPPENAS staff on the use of the computer software and the techniques used in the report preparation.

The work activities involved the following:

- Interview of senior fertilizer management officials of fertilizer and fertilizer-related institutions to collect and evaluate fertilizer and fertilizer-related data and information.
- Development of a Lotus spreadsheet model as an aid to determine farmers' income at various fertilizer farmgate prices.
- Skill transfer training for BAPPENAS staff on the use of computer software and techniques used in report preparation.

Briquetting Project

As part of a joint agreement between IFDC and the Indonesian Fertilizer Producers Association (APPI), an IFDC engineer, in conjunction with Indonesian counterparts, reviewed and assessed the production of urea briquettes.

Since 1982 the Agency for Agricultural Research and Development, the Ministry of Agriculture (Indonesia), and IFDC have collaborated on the agronomic evaluation of urea supergranules (USG) in transplanted rice. In 1986, to identify a scheme to supply USG to Indonesian rice farmers, IFDC, Agency for Agricultural Research and Development (AARD), the Centre for Soil Research, and the Metal Industries Development Centre (MIDC) tested a village-level Chinese-made briquetter and demonstrated the technical feasibility of producing 1-g oblate-shaped USG or urea briquettes by using prilled urea, urea fines, or urea dust as feedstock.

Although in principle some USG were made for brief intermittent periods, modifications of the machine were required to improve its overall performance and operating life. Subsequently, in 1987 the Chinese briquetter was modified, and its improved production performance was demonstrated at the annual review meeting of the Fertilizer Efficiency Program in Indonesia. This successful urea briquetter production demonstration and improved agronomic performance of deep-placed urea briquettes prompted the Government of Indonesia to requisition hundreds of locally fabricated urea briquetters to be operational by the end of 1992.

In this review, the operation of various examples of briquetting machines made in Indonesia was examined to evaluate their condition and performance. These briquetters are based on a further and improved version of the MIDC/IFDC briquetter, which is a modification of the village-level briquetter manufactured by the Chinese.

In addition, during the review, possible design and operational problems were identified. A modification and testing program was established and implemented by APPI. It was recommended that a new generation of briquetters be developed to allow the successful completion of the project and to be able to achieve the goals and targets set by the Government of Indonesia, that is, to produce urea briquettes for application on paddy rice so as to increase rice yield, improve nitrogen efficiency, and reduce environmental pollution. The existing briquetters could be used for workshops and training exercises.

Malaysia

The NPK granulation plant operated by FPM Sendirian Berhad, a joint-venture Malaysian company, completed 9 years of commercial operation in 1991. The granulation process is unique in that it is based on urea as the primary source of nitrogen and unacidulated phosphate rock as the major source of P_2O_5. During 1991 FPM continued work on optimizing its production formulations and production efficiency. FPM also explored a number of product and process variations that would enhance its export marketing opportunities. IFDC provided technical assistance to FPM at a low level, primarily in the area of optimization of new product formulations and the evaluation of alternative raw material sources.

Saudi Arabia

Al-Rasheed Agriculture and Landscaping Enterprises of Saudi Arabia requested that IFDC perform tests on the production of fortified humate. Humate is marketed by Humate Resources Incorporated as a soil conditioner, water-holding agent, micronutrient source, etc. The company claims that the product increases root growth, chlorophyll content, and nutrient uptake and improves the quality of plants.

The main objective of this project was to evaluate the production of (1) a mixture of humate, ammonium sulfate, micronutrients, and a phosphorus source (4-4-0) grade and (2) a mixture of humate and ammonium sulfate (4-0-0-4S) grade with both to be made by the compaction-granulation process. Agronomic trials on the materials will be conducted in Saudi Arabia.

In conclusion, production of granular fortified humate seems feasible, based on the results obtained in laboratory-scale compaction equipment operated under continuous processing conditions. It was found that the humate must be relatively dry for proper feeding and compacting.

It was recommended to proceed to large-scale testing using a commercial compactor to obtain data to estimate the equipment required for a prescribed production rate. In addition, it was also recommended to perform a prefeasibility study on plant investment and production costs to manufacture granular humate enriched with nitrogen, phosphorus, and micronutrients after the location and capacity of the plant have been determined.

Latin America

Chile

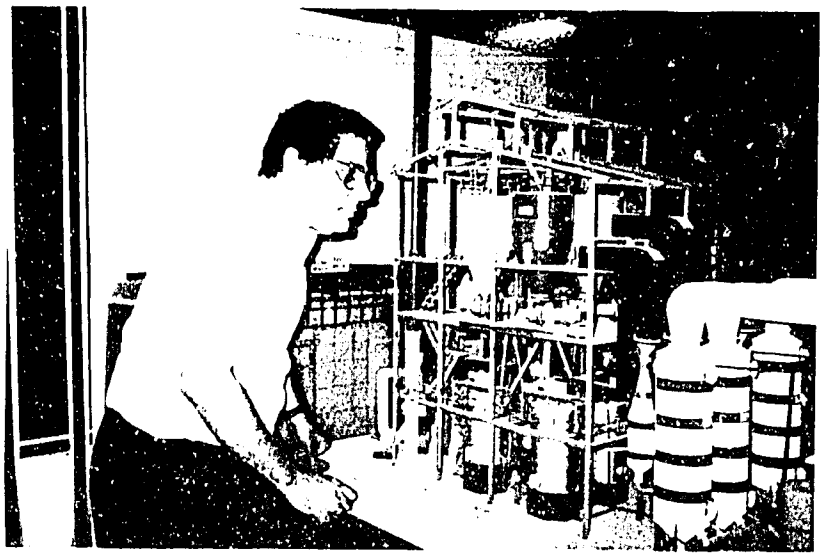
At the request of SQMC, a commercial division of Soquimich (SQM), an IFDC engineer was sent to Chile during 1991 to assist with the evaluation of a TSP complex located at Penco. SQM was considering entering into a joint venture with the owner of the complex, the Compañía Sud Americana de Fosfatos S.A. (COSAF). The present complex was completed in 1968 and, after a series of problems, reached design production capacity in 1973. Financial problems and foreign competition caused the complex to cease operations from 1976 to 1981. Since resuming operation the complex does not produce sulfuric or phosphoric acids but does produce TSP using imported phosphoric acid.

SQM, the major producer of fertilizer in Chile, feels that assuming control of COSAF would allow them to implement plant renovations and marketing strategies that would benefit both the country and the company. To assist the SQM Board of Directors in making a decision, the IFDC engineer technically assessed the complex for soundness of process design, equipment, and plant capacity. The results of this assessment were presented to SQMC in a technical report along with an executive summary and a videotaped presentation. The results of the Board's deliberations are not yet known.

Colombia

Abonos Colombianos S.A. (ABOCOL), a private company with fertilizer production facilities at Cartagena, Colombia, has been a major producer of compound granular fertilizers since 1963. Previously, its management contracted with IFDC for the basic process engineering of a major modification to update its technology so as to increase nutrient efficiency and production capacity and flexibility, while reducing corrosion problems, power consumption, and ambient pollution.

As a followup, IFDC was asked to visit the plant site and review the detail engineering prepared by a local company from IFDC's process design package. In the review, IFDC ensured that the fundamentals of the process design were present and that the latest available technology had been incorporated.



(Photo by Efraín Manotas, ABOCOL)

Jorge Polo, IFDC Senior Project Analyst, inspects a model of the expansion of ABOCOL's NPK plant.

As a result of the different phases of work performed by IFDC, it is expected that ABOCOL will begin operating the plant at an increased production capacity during 1992. The operation of the modified plant will be simplified and will result in a system more easily monitored and controlled, which will permit steadier and more efficient production of uniform products.

Costa Rica

A second study analyzing the financial market value of Fertilizantes de Centro America, Costa Rica (FERTICA) was performed for Fiduciaria de Inversiones Transitorias (FINTRA) of San José, Costa Rica. FERTICA, a state-owned enterprise, is a major fertilizer producer, while FINTRA is an organization created for planning and implementing the privatization of government-owned companies in Costa Rica.

This second study was required because the present situation of FERTICA and its market has changed since the previous one was implemented: the company's debt was restructured, price restrictions on fertilizers were lifted, and the fertilizer demand in the country has had a healthy increase.

As in the first study performed, the information collected during an in-country visit was used to analyze the present cost structure of the company, project the expected fertilizer sales, and perform financial analyses of three alternative configurations of FERTICA. The results from the analyses were used to generate net present values for the company to be used by FINTRA in recommending a fair market value for the company to FERTICA and the Government.

Mexico

IFDC and Sociedad Cooperativa del Distrito de Altar S.C.L. (SOCOADA) signed an agreement for IFDC to provide technical services, training, and agronomic services to SOCOADA. As part of this agreement, SOCOADA requested IFDC to provide a marketing specialist and a chemical engineer to go to Caborca, Mexico. The two IFDC staff members went to Caborca to obtain local information for use in a study to determine SOCOADA's future fertilizer strategy.

The main objectives were to:

- Gather present market information to determine fertilizer market demand and possible changes in this market that will influence the fertilizer product mix.
- Determine the present product mix and the equipment available to service the products.
- Assess the cropping patterns and determine possible cropping patterns in the future.
- Review the soil testing procedures and technical support program and make suggestions.
- Make recommendations on changes that might be warranted in dry and liquid fertilizers in relation to market and manufacturing potential and equipment for distribution.

As for the future, the current idea of the cooperative is to maintain the current market area with no major expansion. Some other projects (production of UAN-32, liquid ammonium sulfate, and liquid potash) discussed with the IFDC team are justified because of the low investment cost required. IFDC recommended against a 10-34-0 plant due to the

investment. SOCOADA was also advised on the production of liquid NPK fertilizers. If SOCOADA continues to buy solid ammonium nitrate, ammonium sulfate, and potash for distribution in the area, SOCOADA can start producing these as liquid fertilizers and could very easily produce liquid NPK materials in the future. It was recommended that SOCOADA perform a prefeasibility study to obtain reliable data on the economics of any new venture requiring significant investment.

Human Resource Development

During 1991 IFDC embarked on a new phase of human resource development activities. These activities are designed to meet the challenges evolving in the marketplace relating to new developments in the agriculture sector in general and the nutrient supply sector in particular. These challenges require expanded knowledge and skill of the manpower of developing countries in the areas of environment, sustainability, designing of policies, and strengthening of the nutrient supply sector. Consequently, the human resource development activities were focused on these areas in 1991.

Thirty-two programs, both general group and specialized, were conducted in 1991 in which 423 scientists, research workers, engineers, economists, statisticians, soil scientists and agronomists, and marketing and distribution managers participated. They represented 54 countries and included 33 women participants. This number reflects an increase of 23% in the number of programs and 36% in the number of participants as shown below.

	1990	1991	% of increase
Total programs	26	32	23
Total participants	311	423	36

General Group Programs

General group programs are offered to participants on a global basis as training programs or workshops. During 1991 the general group programs consisted of 10 offerings: six were conducted in the United States and four overseas (Table 6). The offerings varied from 1 to 5 weeks in duration and addressed the areas of fertilizer marketing, production process and technology, sustainability of crop production, environmental impact, use efficiency of plant nutrients, and policies. Of the 10 offerings, two were workshops, both addressing for the first time new subject areas: (1) Developing the Fertilizer Dealer—Emphasizing the Small-Farm Sector and (2) Environmental Impact of Ammonia and Urea Production Units.

Another new offering was a 2-week program on Plant Nutrient Management for Sustainable Agriculture. Sustainable agriculture also received added thrust in a new 2-week offering entitled Training Workshop on Policy Issues Affecting Fertilizer Sector

Table 6. 1991 IFDC group training programs

Program	Duration	Location
Developing the Fertilizer Dealer--Emphasizing The Small-Farm Sector	1 week	Kingston, Jamaica
Environmental Impact of Ammonia and Urea Production Units	1 week	Bombay, India
Computer Simulation for Plant Growth and Nutrient Management	2 weeks	Muscle Shoals, Alabama, U.S.A.
Modern Techniques in Fertilizer Distribution and Handling	3 weeks	United Kingdom, Republic of Ireland, Netherlands, Belgium, West Germany
Agroeconomic Evaluation for Development of Fertilizer Recommendations	3 weeks	Muscle Shoals, Alabama, U.S.A.
Fertilizer Marketing Management Training Program	5 weeks	Muscle Shoals, Alabama, U.S.A.
Policy Issues Affecting Fertilizer Sector Development and Sustainable Agriculture	2 weeks	Muscle Shoals, Alabama, and Washington, D.C., U.S.A.
Plant Nutrient Management for Sustainable Agriculture	2 weeks	Muscle Shoals, Alabama, U.S.A.
Financial, Economic, and Environmental Impact Analysis for Fertilizer Sector Projects	3 weeks	Muscle Shoals, Alabama, U.S.A.
Fertilizer Marketing Training Program	2 weeks	Bangkok, Thailand

Development and Sustainable Agriculture. Another first-time offering was the Training Program on Financial, Economic, and Environmental Impact Analysis for Fertilizer Sector Projects. The European traveling program on Modern Techniques in Fertilizer Distribution and Handling, Computer Simulation for Plant Growth and Nutrient Management, and Fertilizer Marketing Training Program attracted several participants. The breakdown of the ten 1991 programs by subject is as follows:

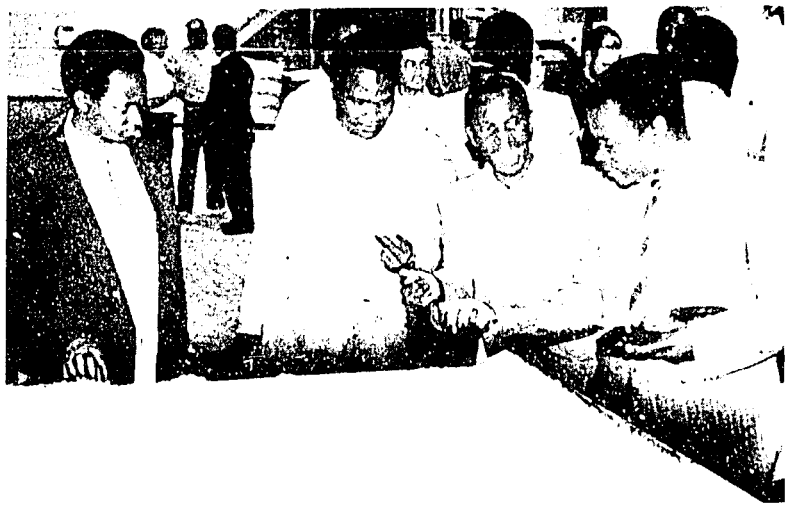
Environment	1
Sustainable agriculture	1
Policy issues	1
Fertilizer sector	1
Fertilizer use efficiency	2
Fertilizer marketing	4
	10

IFDC Pilot Plant Operations Coordinator, George W. Bolds, takes a group of training program participants on a tour of the IFDC Pilot Plant.

(Photo by Charles Butler)

These training participants examine urea briquettes produced by the IFDC briquetter.

(Photo by Charles Butler)



In the conduct of general group programs, IFDC enlisted the support and cooperation of several organizations that provided faculty and extended invitations for field visits. These included NiFTAL, USAID, World Bank, USDA, FAO, Fertiliser Association of India (FAI) (India), Fertilizer Advisory Development and Information Network for Asia and the Pacific (FADINAP) (Thailand), UNIDO (Austria), UNDP, Centro Agronomico Tropical de Investigacion y Ensenanza (CATIE) (Costa Rica), MANAH and PETROFERTIL (Brazil), Ohio State University, Phosphate and Potash Institute (PPI) (Ecuador, Canada, and U.S.A.), Canadian International Development Agency (CIDA), University of West Indies, University of Florida, International Fertilizer Industry Association, Limited (IFA) (France), Nederlands Meststoffen Instituut (NMI) (Netherlands), Purdue University, IFPRI, Environmental Protection Agency (EPA), The Fertilizer Institute (TFI), WINROCK, Florida Phosphate Council, USDC, Ministry of Agriculture and Cooperatives (Thailand), and public- and private-sector commercial organizations in the developed and developing countries.

Specialized Programs

The specialized programs numbered 22 and covered a wide array of subjects that included phosphate rock characteristics, fertilizer technology, suspension fertilizers, crop modeling, irrigation, and an in-country marketing program in Zambia (Table 7).

Evaluation

Of the total of 423 participants, 319 participated in 10 general group programs and 104 in 22 specialized programs. The 10 general programs were rated by the participants through an evaluation form administered on the concluding day of the 10 programs. These programs received an average rating of 4.07 corresponding to "very good" on a scale of 1 to 5—1 being poor and 5 being excellent.

Larry Larkin (left), Plant Manager, IMC Fertilizer, Inc., Florence, AL (U.S.A.) discusses the operation of the IMC plant with an FMMTP training participant, Tive Etaorokpor Okpalefe, Principal Agricultural Officer, Federal Ministry of Agriculture and Natural Resources, Nigeria.

(Photo by Charles Butler)

Table 7. IFDC specialized training programs, 1991

Program	Participants: Country	Participants: Number	Program Length (Days)
Fertilizer Production			
Studies of Phosphate Rock	U.S.A.	1	12
Phosphate Rock Characterization	Mauritania	1	75
General Fertilizer Technology	Venezuela	1	345
General Fertilizer Technology	United Arab Emirates	1	21
Suspension Fertilizer	China	1	180
Granulation/Fluid Fertilizer	India	1	20
Fertilizer Marketing			
Marketing	Bangladesh	1	20
Marketing Management	Bangladesh	9	21
Marketing Training (In-Country)	Zambia	26	5
Commercial Credit Program	Bangladesh	10	30
Fertilizer Distribution	Bangladesh	14	14
Banking Management	Bangladesh	8	17
Fertilizer Use Research			
Use/Efficiency in the Tropics	Honduras	20	10
Crop Modeling	France	1	26
Crop Modeling	Philippines	1	5
Crop Modeling	Tanzania	1	1
Crop Modeling	Malawi	1	1
Soil Fertility	Mali	1	5
Soil Fertility	Mali	1	270
Irrigation/Fertilizer Application	Pakistan	2	32
Fertilizer Sector/Other			
Computer Uses	India	1	360
Instrumentation-Raw Material Analysis	Togo	1	

Gene T. Harris (center), IFDC Economist and Manager of the Fertilizer Marketing Management Training Program, takes the training participants on a tour of Shaw Farms, Athens, AL (U.S.A.). Charles Meadows, Manager of Shaw Farms, is on the right.

(Photo by Charles Butler)

The 1991 UNDP review of IFDC's human resource development program concluded that the training programs were relevant to the needs of the developing countries and should be continued. IFDC will continue its efforts—in a changed environment—in human resource development activities and plans to organize up to 10 programs in 1992.

IFDC 1991 Donors

Der Bundesminister für Wirtschaftliche Zusammenarbeit (BMZ)
Directoraat Generaal voor Internationale Samenwerking (DGIS)
International Development Research Centre (IDRC)
W. K. Kellogg Foundation
Research Institute for Tropical Agriculture (IRAT)
Rockefeller Foundation
Sociedad Quimica y Minera de Chile (SQM)
United Nations Development Programme (UNDP)
United Nations Industrial Development Organization (UNIDO)
U.S. Agency for International Development (USAID)
World Bank
World Phosphate Institute (IMPHOS)

International Fertilizer Development Center 1991 Projects

Project/Purpose	Funding Source	(U.S. Dollars)	Duration
Global			
Unrestricted			
Research and Development Grant:			
To assist farmers in developing countries to meet the plant nutrient demands of their crops, increase farm income, promote national food security with sustainable agriculture and protect the environment from agricultural degradation and pollution from fertilizer production and use.	USAID	3,100,000 annually	1975 - continuing
	World Bank	500,000 annually	1989 - continuing
Africa Center Development Grants:			
An assistance grant for establishment and maintenance of the IFDC West Africa Center.	BMZ DGIS	1,000,000	1987-91
Restricted			
Development and promotion of sound strategies to produce and use fertilizers to sustain agriculture while at the same time affording protection to the environment.	UNDP/ World Bank	5,500,000	1990-95
Africa			
Collection and Dissemination of Fertilizer Information - Phase II			
This project aims at improving the collection, analysis, and dissemination of Fertilizer Trade and Marketing Information in Sub-Saharan Africa with emphasis on West Africa.	DGIS	2,838,000	1991-94
Fertilizer Investment for Soil Fertility Restoration			
To identify the constraints to fertilizer adoption in various agroecological zones and to evaluate the impact of various fertilizer investment strategies in selected pilot areas in West Africa where the conditions for fertilizer adoption appear favorable.	USAID World Bank Rockefeller IRAT IMPHOS	5,200,000	1987-92
Fertilizer Policy Research in Tropical Africa			
A jointly executed project by IFDC and IFPRI aimed at the analysis and formulation of fertilizer policies. A study on the impact of donor intervention, subsidy policies, privatization, price policies, food and politics, and investment policies in the fertilizer and food sector.	USAID	3,700,000	1987-92

Project/Purpose	Funding Source	(U.S. Dollars)	Duration
Fertilizers and Sustainable Agriculture Identifying the role and maximizing the benefits of fertilizer use to the farmer to help meet crop nutrient demands.	UNDP	2,300,000	1990-94
Installation of Laboratory Equipment To install and test laboratory equipment at EFDC.	UNIDO	75,000	1991
Institutionalizing the Privatization of the Fertilizer and Seed Sectors in Ghana To increase food production, particularly by the small-scale farmer, with the expanded use of fertilizer and improved seed and other recommended management practices.	USAID	200,000	1991
On-Farm Evaluation and Adoption To demonstrate that farmer participation is an essential component of the technology transfer process.	IDRC	860,000	1989-92
Studies and Experimental Assessment on NPK (Plus) Conduct an Opportunity Study to assess the potential to produce and consume NPK (Plus) fertilizers in Egypt; carry out technical assistance and training to establish a database and investment analysis unit within EFDC; provide assistance to procure, assemble, and make operational a multipurpose pilot plant.	UNIDO	935,000	1989-93
Training of Rockefeller Visiting Scientist Training of Mr. Elias T. Ayuk to study on-farm evaluation and adoption in West Africa while located at the IFDC West Africa Center.	Rockefeller	80,000	1990/91
Asia			
Fertilizer Distribution and Marketing Consultancy Services to the Government of Bangladesh - Phase II To assist BADC to improve fertilizer marketing by incorporating private-sector concepts and resources.	Gov't. of Bangladesh	9,900,000	1987-91
Fertilizer Marketing Study - Indonesia To assist the Government of Indonesia in the appraisal of the present fertilizer marketing system.	Ministry of Industry	379,400	1991/92

Project/Purpose	Funding Source	(U.S. Dollars)	Duration
Evaluation of the TSP Complex at Chittagong.	USAID	56,000	1991
Technical Assistance to BAPPENAS Report on Indonesia Fertilizer Situation and Outlook.	USAID	42,000	1991
Eastern Europe			
Technical Assistance to Albania To provide the Government of Albania with assistance in transport of existing fertilizer and to resume fertilizer production in a safe, effective, and sustainable manner.	USAID	225,000	1991/92
Latin America			
Pilot-Plant Granulation of NPK Fertilizers To increase the production capacity of a granulation compound NPK fertilizer plant and the elimination of the importation of raw materials.	MONOMEROS	76,000	1990/91
Small Farmer Organization Strengthening Program - Honduras To offer training in the areas of fertilizer procurement, handling and marketing.	USAID	70,000	1991/92
Technical Assistance to ABOCOL Modification and modernization of an NPK plant.	ABOCOL	43,000	1991/92
Technical Assistance to Soquimich Technical and economical evaluation of an SSP plant.	Soquimich	11,500	1991
Technical Assistance to FINTRA Market appraisal of FERTICA.	FINTRA	21,000	1991

Financial Report

50 Hurt Plaza
Suite 1700
Atlanta, GA 30303

Telephone 404 658 1800
Facsimile 404 658 8899

Price Waterhouse

REPORT OF INDEPENDENT ACCOUNTANTS

March 13, 1992

To the Board of Directors of
International Fertilizer Development Center

In our opinion, the accompanying balance sheets and the related statements of revenue, expenses and changes in fund balances, of functional expenses and of cash flows present fairly, in all material respects, the financial position of International Fertilizer Development Center (IFDC) at December 31, 1991 and 1990 and the results of its operations, changes in its fund balances and its cash flows for the years then ended in conformity with generally accepted accounting principles. These financial statements are the responsibility of the organization's management; our responsibility is to express an opinion on these financial statements based on our audits. We conducted our audits of these statements in accordance with generally accepted auditing standards which require that we plan and perform the audit to obtain reasonable assurance about whether the financial statements are free of material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the financial statements, assessing the accounting principles used and significant estimates made by management and evaluating the overall financial statement presentation. We believe that our audits provide a reasonable basis for the opinion expressed above.

Price Waterhouse

INTERNATIONAL FERTILIZER DEVELOPMENT CENTER

BALANCE SHEETS - ASSETS

	December 31, 1991	December 31, 1990
CURRENT FUND		
Cash and cash equivalents	$ 2,305,862	$ 2,500,773
Amounts receivable from donors (Notes 1 and 2)	5,783,340	5,338,454
Other accounts receivable	1,314,807	1,304,284
Advances to employees	103,337	99,769
Supplies inventory (Note 1)	175,800	177,024
Prepaid expenses	405,429	368,783
	$ 10,088,575	$ 9,789,087
NONCURRENT FUND		
Amounts receivable from donors - restricted (Notes 1 and 2)	$ 5,500,749	$ 6,615,625
BUILDINGS AND EQUIPMENT FUND (Note 1)		
Buildings	$ 5,969,171	$ 5,969,171
Equipment	5,143,710	5,340,099
Less - Accumulated depreciation	(7,004,881)	(6,808,860)
	$ 4,108,000	$ 4,500,410

BALANCE SHEETS - LIABILITIES AND FUND BALANCES

	December 31, 1991	December 31, 1990
CURRENT FUND		
Accounts payable	$ 345,380	$ 293,450
Accrued annual and sick leave	1,893,100	1,862,412
Deferred revenue (Notes 1 and 2)	6,796,259	6,269,648
Total liabilities and deferred revenue	9,034,739	8,425,510
Fund balance	1,053,836	1,363,577
	$ 10,088,575	$ 9,789,087
NONCURRENT FUND		
Deferred revenue - restricted (Notes 1 and 2)	$ 5,500,749	$ 6,615,625
BUILDINGS AND EQUIPMENT FUND (Note 1)		
Contract retainage	$ 421	$ 421
Lease obligation (Note 4)	21,693	38,998
Fund balance	4,085,886	4,460,991
	$ 4,108,000	$ 4,500,410

The accompanying notes are an integral part of these financial statements.

INTERNATIONAL FERTILIZER DEVELOPMENT CENTER

STATEMENTS OF REVENUE, EXPENSES AND CHANGES IN FUND BALANCES FOR THE YEARS ENDED DECEMBER 31, 1991 AND 1990

	Current Fund		Buildings and Equipment Fund		Total All Funds	
	1991	1990	1991	1990	1991	1990
Revenue						
Grants (Note 2)	$ 7,785,980	$ 8,702,250			$ 7,785,980	$ 8,702,250
Recovered project costs	4,548,573	4,383,582			4,548,573	4,383,582
Other	313,597	157,514			313,597	157,514
Total revenue	12,648,150	13,243,346			12,648,150	13,243,346
Expenses						
Field programs	3,172,850	3,150,681	$ 87,948	$ 127,739	3,260,798	3,278,420
Research	3,500,614	3,595,782	283,765	208,580	3,784,379	3,804,362
Outreach	3,906,052	3,606,475	54,790	52,120	3,960,842	3,658,595
General and administrative	2,257,998	2,429,952	68,979	86,671	2,326,977	2,516,623
Total expenses	12,837,514	12,782,890	495,482	475,110	13,332,996	13,258,000
Excess (deficiency) of revenue over expense	(189,364)	460,456	(495,482)	(475,110)	$ (684,846)	$ (14,654)
Other changes in fund balances						
Transfers from current fund for equipment acquisitions and capital lease payments	(120,377)	(317,342)	120,377	317,342		
Fund balances, beginning of period	1,363,577	1,220,463	4,460,991	4,618,759		
Fund balances, end of period	$ 1,053,836	$ 1,363,577	$ 4,085,886	$ 4,460,991		

The accompanying notes are an integral part of these financial statements.

INTERNATIONAL FERTILIZER DEVELOPMENT CENTER

STATEMENTS OF FUNCTIONAL EXPENSES FOR THE YEARS ENDED DECEMBER 31, 1991 AND 1990

	Field Programs		Research		Outreach		Administrative		Total Expenses	
	1991	1990	1991	1990	1991	1990	1991	1990	1991	1990
Personnel compensation (Note 3)	$ 1,296,390	$ 1,172,551	$ 1,899,001	$ 1,908,935	$ 1,651,571	$ 1,571,740	$ 1,242,608	$ 1,358,999	$ 6,089,570	$ 6,012,225
Personnel benefits (Note 3)	448,370	451,498	470,186	498,580	352,321	391,158	291,977	311,901	1,562,854	1,653,137
Travel and transportation	476,558	380,760	300,030	253,521	795,341	430,498	193,217	174,855	1,765,146	1,239,634
Occupancy	38,036	45,373	228,483	257,202	121,374	133,100	114,242	128,601	502,135	564,276
Telephone and telegraph	86,008	84,326	38,811	26,491	81,867	39,945	34,260	21,474	240,946	172,236
Rental of equipment	46,781	49,367	37,231	23	97,726	98,490	1,414	1,112	183,152	148,992
Contractual research and development	192,995	186,356	116,329	181,915	13,693	18,500		16,392	323,017	403,163
Other contractual services	251,267	367,197	176,956	163,654	456,120	492,862	74,241	170,571	968,584	1,194,284
Institute of International Education fee (Note 3)							136,233	135,192	136,233	135,192
Materials and supplies	301,833	390,309	183,705	258,075	283,762	375,158	142,823	87,882	912,123	1,111,424
Postage	14,249	10,906	11,671	15,407	28,511	24,494	8,344	7,086	62,775	57,893
Insurance	10,363	12,038	38,211	31,979	23,766	30,530	18,639	15,887	90,979	90,434
Miscellaneous	3,609	21,314	91,258	1,441	2,644	804	290	17,706	97,801	41,265
Total expenses before depreciation	3,176,459	3,171,995	3,591,872	3,597,223	3,908,696	3,607,279	2,258,283	2,447,658	12,935,315	12,824,155
Depreciation of buildings and equipment	84,339	106,425	192,507	207,139	52,146	51,316	68,689	68,965	397,681	433,845
Total expenses	$ 3,260,798	$ 3,278,420	$ 3,784,379	$ 3,804,362	$ 3,960,842	$ 3,659,595	$ 2,326,977	$ 2,516,623	$ 13,332,996	$ 13,258,000

The accompanying notes are an integral part of these financial statements.

INTERNATIONAL FERTILIZER DEVELOPMENT CENTER

STATEMENTS OF CASH FLOWS FOR THE YEARS ENDED DECEMBER 31, 1991 AND 1990

	1991	1990
Cash flows from operating activities		
Deficiency of revenue over expenses	$ (684,846)	$ (14,654)
Adjustments to reconcile deficiency of revenue over expenses to net cash provided by operating activities		
Depreciation	397,681	433,845
Loss on disposal or donation of equipment	94,191	41,265
Changes in assets and liabilities		
Decrease (increase) in receivables from donors	669,990	(4,450,747)
(Increase) decrease in advances to employees	(3,568)	32,591
Increase in other accounts receivable	(10,523)	(378,863)
(Increase) decrease in prepaid expenses	(33,036)	14,887
Decrease (increase) in supplies inventory	1,224	(26,743)
Increase in accounts payable and accrued expenses	82,618	97,754
(Decrease) increase in deferred revenue	(588,265)	4,349,925
Net cash (used in) provided by operating activities	(74,534)	99,260
Cash flows from investing activities		
Capital expenditures	(103,072)	(299,776)
Net cash used in investing activities	(103,072)	(299,776)
Cash flows from financing activities		
Principal payments under capital lease obligation	(17,305)	(17,566)
Net cash used in financing activities	(17,305)	(17,566)
Net cash flow	(194,911)	(218,082)
Beginning cash and cash equivalents	2,500,773	2,718,855
Ending cash and cash equivalents	$ 2,305,862	$ 2,500,773

The accompanying notes are an integral part of these financial statements.

NOTES TO FINANCIAL STATEMENTS

1. ORGANIZATION AND ACCOUNTING POLICIES

International Fertilizer Development Center (IFDC) is a nonprofit organization incorporated October 7, 1974 under the state laws of Alabama. On March 14, 1977, IFDC was designated as a public international organization by executive order of the President of the United States. The purpose of the organization is to improve fertilizers and knowledge of fertilizer uses in developing countries through research and development, technical assistance and training and communications.

In the event of dissolution, the articles of incorporation provide that the residual assets of the organization will be turned over to one or more tax exempt organizations or to the federal, state or local government for exclusive public purpose.

The accounts of IFDC are maintained on the accrual basis. The following is a summary of significant accounting policies:

A. Buildings and equipment are stated at cost. Depreciation is computed on the straight-line method over estimated useful lives ranging from three to thirty-five years.

B. Grants are recorded as receivable in full at the date of the grant with revenue recognition deferred until corresponding expenses have been incurred. Contributions for reimbursable costs are recognized as project costs are incurred.

Revenue is restricted to the extent it is to be used in accordance with the purpose specified by the grant. Restrictions generally include a specified project or goal within a particular geographic region.

C. Inventories of supplies are valued at the lower of cost or replacement cost, cost being determined on a first-in, first-out basis.

D. IFDC is exempt from federal income taxes as a publicly supported organization under Section 501(c)(3) of the Internal Revenue Code.

E. For purposes of the statement of cash flows, IFDC considers certificates of deposit with an original maturity of three months or less to be cash equivalents.

2. GRANTS

Grants are summarized as follows:

	Year ended December 31,			
	1991		1990	
	Restricted	Unrestricted	Restricted	Unrestricted
Grants received				
United States Agency for International Development (AID)	$ 223,527	$ 3,100,000	$ 52,904	$ 3,398,000
United Nations Development Program (UNDP)			2,900,000	
International Development Research Centre (IDRC)	213,050		47,243	
Rockefeller Foundation	240,000		60,000	
Directoraat Generalaal voor Internationale Samenwerking (Netherlands) (DGIS)	2,923,925		132,297	
World Bank		770,000	5,500,000	770,000
Der Bundesminister fur Wirshaftliche Zusammenarbeit (BMZ)	47,297		128,400	
	3,647,799	3,870,000	8,820,844	4,168,000
Amounts deferred during prior year	9,800,575	2,895,789	5,863,973	2,569,125
	13,448,374	6,765,789	14,684,817	6,737,125
Less - amounts deferred to future periods	(10,018,832)	(2,240,824)	(9,800,575)	(2,895,789)
Other adjustments	(168,527)		(23,328)	
Revenue recognized in current period	$ 3,261,015	4,524,965	$ 4,860,914	3,841,336
		3,261,015		4,860,914
Total restricted and unrestricted		$ 7,785,980		$ 8,702,250

In addition to grant amounts deferred to future years, as indicated above, deferred revenue at December 31, 1991 and 1990 includes $37,352 and $188,909, respectively, of cash collected on reimbursable cost projects for which revenue has not been recognized.

During 1991, IFDC received restricted grants related primarily to work in Africa. The most significant of these grants was received from DGIS (Netherlands) and expires in 1994. Grants were received from IDRC (Canada) and the Rockefeller Foundation for fertilizer research and training in Africa. Also, a restricted grant was received from AID for policy research in Africa.

The restricted grants received in 1990 related to work in Africa and other developing countries. The UNDP grant was obtained for purposes of performing fertilizer research in West Africa. In addition, a grant was obtained through the World Bank and guaranteed by UNDP for performing fertilizer research and improving fertilizer technologies in developing countries. These grants will expire in 1994 and 1993, respectively. Additional funding to support the Togo Center was obtained from DGIS during 1990 and this grant expired in June 1991.

Receivables from donors at December 31, 1991 and 1990 are summarized as follows:

	Year ended December 31,			
	1991		1990	
	Restricted	Unrestricted	Restricted	Unrestricted
AID	$ 892,400	$ 1,729,027	$ 1,785,112	$ 1,685,788
DGIS	2,257,900		343,255	
UNDP	1,703,052		2,252,684	
IDRC	310,764		521,699	
Rockefeller Foundation	120,000		120,000	
World Bank	4,270,946		5,026,750	
BMZ			218,791	
	9,555,062	1,729,027	10,268,291	1,685,788
Less - Noncurrent portion	5,500,749		6,615,625	
	$ 4,054,313	1,729,027	$ 3,652,666	1,685,788
		4,054,313		3,652,666
Total restricted and unrestricted		$ 5,783,340		$ 5,338,454

3. INSTITUTE OF INTERNATIONAL EDUCATION

IFDC has a contract with the Institute of International Education (IIE) whereby all payroll administrative functions are performed by IIE; IFDC makes advances monthly to fund salaries, employment taxes and fringe benefits.

4. CAPITALIZED LEASE OBLIGATIONS

IFDC leases office equipment under agreements classified as capital leases. Assets recorded under capital leases are included in property and equipment as follows:

	December 31, 1991	December 31, 1990
Office Equipment	$ 130,672	$ 130,672
Less: accumulated depreciation	40,450	40,818
	$ 90,222	$ 89,854

As of December 31, 1991, future minimum lease payments are as follows:

1992	$ 21,126
1993	21,126
	42,252
Less - Amounts representing interest	3,254
Present value of minimum lease payments	$ 38,998

Staff

(as of December 31, 1991)

Office of the President

Paul J. Stangel, President and Chief Executive Officer
Amitava H. Roy, Executive Vice President and Chief Operating Officer
M. Terry Frederick, Development Officer
Amber N. Hammock, Correspondence Secretary
Samuel C. Muchena, Managing Director—ACFD
David B. Parbery, Managing Director[3]
Debra R. Rutland, Executive Secretary
Marie K. Thompson, Public Relations Officer

Administration Division

Marjorie R. Brashier, Director
Kaye F. Barker, Budget Officer
Jacqueline A. Berrens, Assistant Librarian
Madeline W. Bevis, File Clerk
Elizabeth B. Bosheers, Mail/Stock Clerk
Charles E. Butler, Photographer/Media Technician
Glenda Carter, Accounting Clerk
Linda B. Cornatzer, Word Processing Specialist
C. David Edwards, Personnel Officer
Brenda S. Elmore, Word Processing Specialist
Janice C. Gautney, Word Processing Specialist
Jane L. Goss, Word Processing Specialist
Alicia K. Hall, Word Processing Specialist
Vickie J. Hollandsworth, Word Processing Specialist
Mary C. Irons, Proof Reader[3]
W. Diane Kasmeier, Assistant Purchasing Agent
James M. Kelly, Purchasing Agent
Terry L. McGee, Graphic Artist/Media Technician
Jean G. Meyer, Mail Clerk[2]
Brenda G. Peden, Accounting Clerk
Faye Predmore, Receptionist
Jean S. Riley, Librarian
Elizabeth N. Roth, Editor
Flora M. Rudolph, Technical Illustrator[1]
Patricia F. Sandlin, Word Processing Specialist[1]
Debra S. Shedd, General Accountant
Carol S. Slaton, Word Processing Specialist
Patricia H. Spires, Clerk
James C. Starkey, Graphic Designer/Illustrator
Marie R. Stribling, Coordinator, Word Processing Center
Joy M. Thompson, Accountant
Michael O. Thompson, Visitor Relations Officer
Donna W. Venable, Word Processing Specialist
David B. Wright, Mail Clerk
Lynda F. Young, Editor/Coordinator-Communications

Resources Management Research and Development Division

Dennis H. Parish, Director
Ernest R. Austin, Instrumentation Specialist
Carlos A. Baanante, Economist
Walter E. Baethgen, Soil Scientist/Biometrician
Sherry R. Bayless, Database Operator
Billy W. Biggers, Jr., Analytical Laboratory Supervisor[1]
Karen S. Billingham, Laboratory Supervisor
James E. Brink, Geographic Information Specialist/Programmer
Balu L. Bumb, Policy Economist
Roland J. Buresh, Soil Scientist[1]
Kristi L. Burghed, Chemical Laboratory Analyst
Bernard H. Byrnes, Soil Scientist
Celia J. Calvo, Chemical Laboratory Analyst
Gildardo Carmona, Research Associate/Greenhouse Supervisor
Margaret M. Chien, Research Associate[1]
Sen H. Chien, Soil Chemist
C. Bruce Christianson, Soil Scientist
Jerry R. Clemmons, Research Chemist
John T. Colagross, Electronics Specialist
Carol C. Cole, Chemical Laboratory Analyst[1]
Michael W. Danley, Greenhouse Technician[1]
R. Dwane Duncan, Consultant-Analytical Chemist
Ronnie L. Faires, Greenhouse Supervisor
Delilah A. Forsyth, Administrative Secretary
Dennis K. Friesen, Soil Scientist
Amadou Gakou, Visiting Scientist[1]
Ephraim M. Govere, Visiting Research Associate
Deborah T. Hellums, Research Associate
Julio Henao, Biometrician
Vaughn K. Henry, Greenhouse Technician
Leella S. Holt, Research Associate[1]
R. Gary Howard, Chemical Laboratory Analyst
Martha P. Hurley, Chemical Laboratory Analyst[1]
Vanessa E. Keel, Chemical Laboratory Analyst
Maurice O. Klein, Special Project Engineer

Talaat A.B. Lawendy, Minerals Engineer
L. Alfredo León, Soil Scientist
Khalidou Lo, Visiting Scientist[1]
Benjamin C. Malone, Chemical Laboratory Analyst
Guerry H. McClellan, Scientific Advisor[1]
Raman G. Menon, Soil Scientist
G. Erick Peters, Research Chemist
Douglas C. Petty, Student Worker[1]
Nancy A. Potter, Administrative Secretary
Janet J. Rumbley, VAX Operator
Narayan K. Savant, Soil Chemist
Glenda F. Smallwood, Computer Programmer
Upendra Singh, Systems Modeler/Soil Scientist
Henry Ssali, Soil Scientist
M. Patricia Stowe, Research Assistant
B. Keith Tays, Chemical Laboratory Analyst
Thomas P. Thompson, Rural Sociologist
Philip K. Thornton, Systems Modeler
Steven J. Van Kauwenbergh, Mineralogist/Petrographer
Wan Xia, Systems Modeler Research Assistant

Outreach Division

Owen W. Livingston, Director
Loren E. Ahlrichs, Marketing Specialist
John H. Allgood, Market Analyst
Daris H. Belew, Correspondence Secretary
Bobby W. Biggers, Research Chemist
William S. Blankenship, General Laborer
George W. Bolds III, Pilot-Plant Operations Coordinator
Robert C. Bosheers, Engineering Research Technician
Michael W. Chafin, Research Technician
W. Edward Clayton, Transportation/Distribution Specialist
Doyce E. Couch, Assistant Maintenance Coordinator
Thomas E. Evers, Research Technician
Evelyn Freeman, Secretary
Ram S. Giroti, Training Administrator
Frances H. Glover, Correspondence Secretary
D. Ian Gregory, Marketing Specialist
Gene T. Harris, Economist
Regina S. Harris, Marketing Research Assistant
Michael D. Hellums, Maintenance Technician[1]
Gary L. Hines, General Helper
Deborah B. King, Administrative Secretary
Jose R. Lazo de la Vega, Special Project Engineer
Jimmy L. McGee, Technician
Ann H. Mock, Correspondence Secretary[2]
T. Alan Nix, Research Associate
Jorge R. Polo, Senior Project Analyst
Sanjit K. Rao, Visiting Scientist
H Dale Richards, Warehouse Technician[1]
Johnnie W. Riley, Maintenance Coordinator
David W. Rutland, Physical Properties Specialist
James J. Schultz, Fertilizer Production Specialist
Edgar Soto M., Visiting Chemical Engineer[1]
Linda W. Trousdale, Information/Marketing Associate
Catalino C. Yaptenco, Jr., Marketing Specialist
Donald R. Waggoner, Chemical Engineer
Xun Zeng, Visiting Scientist

Asia Division

Kenneth L. Moots, Director and Chief of Party
Ray B. Diamond, Dealer Development and Training Consultant
Zahedur R. Kazi, Project Liaison Officer
Surjit S. Sidhu, Credit Consultant

IFDC-Africa

A. Uzo Mokwunye, Director
Konadu Acheampong, Junior Sociologist
Ketline Adodo, Associate Editor
Ama Adorgloh, Research Assistant
Kossivi Elessessi Adze, Secretary
Isabelle Adzoh, Administrative Secretary
Komi Adzomada, Administrative Officer
Edi Afegbedzi, Administrative Assistant
Kokoe Aguessou, Janitor
Komlavi Allaglo, Receptionist
Kodjo Mawali Alognikou, Research Assistant
Akolly Amegashie, Computer Specialist
Kouassi Amegnido, Driver
Kodjo Amelamedi, Field Technician
Marc Andre, Marketing Specialist
Yao Anku, Research Assistant[1]
Dofui Anthony, Secretary
Konou Fogan Ayikpe, Driver
Elias T. Ayuk, Rockefeller Foundation Fellow[a]
Kowu Komi Azorbly, Maintenance/Technician
Andre M. Bationo, Soil Scientist

Dodgi Biakou, Janitor
Michael M. Connolly, Head of Communications
Moisette D'Almeida, Secretary[1]
Kossi Dahoui, Associate Economist
Ulrich Diekmann, Agronomist[b1]
Folly Dosseh, Electronics Technician
Kossi Dzekpo, Guard (Field)
Kossi Edihe, Driver
Koffi Favide, Field Technician
Afiba Fiamo, Translator[1]
Yawovi Fianyo, Mechanic
Irene Gaye, Financial Officer
Heni G. M. Gerner, Quantitative Economist/Data Manager[c]
Barthelemy Honfoga, Research Assistant
Folly Houessou, Guard (Field)
Ampah K.C. Johnson, Geologist
Kossivi Koukoude, Field Technician
Kayi Koulekey, Librarian
Koffi Kowou, Field Technician
Agbeve Lawson, Secretary
Antyama Massada, Secretary
Vivon Mawugbe, Driver
Komi Moussa, Janitor
Hans Werner Mueller, Soil Scientist[d1]
Amoui N'Danou, Research Asistant
Joseph G. Nagy, Economist[1]
Yanick Nicolas, Administrative Secretary[1]
Dodji Oda, Driver
Daniel Pierre, Soil Scientist
Ahli K. Pinto-Toyi, Junior Agronomist/Farm Manager
Dennis Pouzet, Agricultural Economist[e]
Olufemi Modufe Pratt, Desktop Publisher Assistant
Edward R. Rhodes, Agronomist
Anani Sakiti, Research Assistant
Joseph Sedgo, Soil Scientist
Mabel Suppey, Secretary
Alli Witta Tchamsi, Janitor
Jacob F. Teboh, Agricultural Economist
Kokouvi Tsogbe, Field Technician
Komlan Wogomebu, Accountant

[1]Left during 1991.
[2]Retired during 1991.
[3]Extended leave.

a. Rockefeller Fellow.
b. Seconded to IFDC by the German Volunteer Service.
c. Seconded to IFDC by Directoraat Generaal Voor Internationale Samenwerking (Netherlands).
d. Seconded to IFDC by Bundesanstalt für Geowissenschaften und Rohstoffe.
e. Seconded to IFDC by Centre de Coopération Internationale en Recherche Agronomique pour le Développement.

IFDC Board of Directors

(as of December 31, 1991)

Chairman Emeritus
Dr. John A Hannah (U.S.A.)
President Emeritus
Michigan State University
U.S.A.

Chairman
Dr. W.David Hopper (Canada)
Senior Vice President
Haldor Topsoe, Inc.
Washington D.C.
U.S.A.

Vice Chairman
Mr. Joseph C. Wheeler (U.S.A.)
Director, Programme Integration
United Nations Conference on
Environment and Development
Switzerland

Mr. Yaovi Adodo (Togo)
Minister of Foreign Affairs
and International Cooperation
Togo

Dr. Eliseu Roberto de Andrade Alves (Brazil)
Former President
EMBRAPA and CODEVASF
Brazil

Dr. Anton Amberger (Federal Republic of Germany)
Professor
Institute of Plant Nutrition
Technical University of Munich
Federal Republic of Germany

Dr. Hiram Grove V. (Chile)
Executive President
Institute of Agricultural Research (INIA)
Chile

Mr. Pratap Narayan (India)
Executive Director
Fertiliser Association of India
India

Dr. Christian Pieri (France)
Deputy Director
Institute of Tropical Agronomic
Research
IRAT/CIRAD
France

Dr. Robert E. Wagner (U.S.A.)
President Emeritus
Potash & Phosphate Institute
U.S.A.

Mr. William F. Willis (U.S.A.)
Senior Executive Officer and President
Board Advisory Group
TVA
U.S.A.

Dr. Bukar Shaib (Nigeria)
Former Minister of Agriculture
Nigeria

Ex Officio Member
Dr. Paul J. Stangel (U.S.A.)
President and Chief Executive Officer
IFDC

Ex Officio Member
Dr. Amit H. Roy (U.S.A.)
Executive Vice President and Chief Operating Officer
IFDC

Ex Officio Member
Marjorie R. Brashier (U.S.A.)
Administrative Director
IFDC

*Deceased

IFDC Addresses

(as of July 1992)

Headquarters

IFDC
P.O. Box 2040
Muscle Shoals, Alabama 35662
U.S.A.
Telephone: 205-381-6600
Telex: 810-731-3970
Telefax: 205-381-7408

Other IFDC Offices

IFDC/Dhaka
GPO 3044
Dhaka
BANGLADESH
Telephone: 259642/281508
Telefax: 880-2-883-079

IFDC/Asia Division
House No. 121
Block-F, Road No. 1
Banani Model Town
Dhaka
BANGLADESH
Telephone: 893609

IFDC/CIAT
Apartado Aéreo 6713
Cali
COLOMBIA
Telephone: 57:23-675050
Telex: 05769 CIAT CO.ITT
Telefax: 57:23-647243

IFDC/ICRISAT Sanelian Center
BP 12404
Niamey
NIGER
Cable: ICRISAT, Niamey
Telex: 5406 NI
Telephone: 722529/722725/723697

IFDC/IRRI
P.O. Box 933
Manila
PHILIPPINES
Telephone: 63-2-818-1926
Telex: ITT 45365 RICE INST PM
Telefax: 63-2-8178470

IFDC-Africa
B.P. 4483
Lomé
TOGO
Telephone: 21-79-71
Telex: 5416 CIFDC TG
Telefax: 21-78-17

IFDC/SADCC/ICRISAT
P.O. Box 776
Bulawayo
ZIMBABWE
Telephone: 79563
Telex: 3570 ZIMBABWE
Cable: MATGRIC, Bulawayo
Telefax: 76658

IFDC/ACFD
Ministry of Lands, Agriculture, and Rural Resettlement
Private Bag 7701
Causeway
Harare
ZIMBABWE
Telephone: 706081
Telex: 24789
Telefax: 263-4 727989

Acronyms and Abbreviations

AAP	Agricultural Adjustment Project
AARD	Agency for Agricultural Research and Development
ABOCOL	Abonos Colombianos S.A.
ACFD	African Center for Fertilizer Development
AFID	Africa Fertilizer Information Data Base
AFTMIN	African Fertilizer Trade and Marketing Network
APPI	Indonesian Fertilizer Producers Association
ARS	Agricultural Research Service
ATSP	ammoniated triple superphosphate
BADC	Bangladesh Agricultural Development Council
BAPPENAS	Indonesia National Development Planning Agency
BGR	Bundesanstalt für Geowissenschaften und Rohstaffe
BMZ	Der Bundesminister für Wirtschaftliche Zusammenarbeit
BNEDER	Bureau National d'Etude pour le Développement Rural
BNF	biological nitrogen fixation
CATIE	Centro Agronomico Tropical de Investigacion y Ensenanza
CIAT	Centro Internacional de Agricultura Tropical
CIDA	Canadian International Development Agency
CIMMYT	International Maize and Wheat Improvement Center
CIRAD	Centre de Cooperation International en Recherche Agronomique pour le Developpement
COSAF	Compañía Sud Americana de Fosfatos S.A.
DGIS	Directoraat Generaal voor Internationale Samenwerking
DSR	dry-seeded rice
DSSAT	Decision Support System for Agrotechnology Transfer
DT	days after transplanting
EEC	European Economic Community
EFDC	Egyptian Fertilizer Development Center
EPA	Environmental Protection Agency
ESAFMEN	East and Southeast African Fertilizer Management and Evaluation Network
FADINAP	Fertilizer Advisory Development and Information Network for Asia and the Pacific
FAI	Fertiliser Association of India
FAO	Food and Agriculture Organization of the United Nations
FERTICA	Fertilizantes de Centro America, Costa Rica
FINTRA	Fiduciaria de Inversiones Transitorias
FMMTP	Fertilizer Marketing Management Training Program
Fosmag	magnesium oxide-treated SSP
FPM	FPM Sendirian Berhad
FPRG	Fertilizer Policy Research Group
GIS	Geographic Information System
GOB	Government of Bangladesh
ha	hectare
IBSNAT	International Benchmark Sites Network for Agrotechnology Transfer
IBSRAM	International Board for Soil Research and Management

ICA	Instituto Colombiano Agropecuario
ICRAF	International Council for Research in Agroforestry
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICTA	Instituto de Ciencia y Tecnologiá Agrícolas
IDRC	International Development Research Centre
IER	Institute d'Economies Rurale
IFA	International Fertilizer Industry Association, Limited
IFDC	International Fertilizer Development Center
IFDC-A	International Fertilizer Development Center-Africa
IFPRI	International Food Policy Research Institute
IMPHOS	World Phosphate Institute
INTEVEP	Instituto de Technologica de Venezuela
IRAT	Research Institute for Tropical Agriculture
IRRI	International Rice Research Institute
ISSER	Institute of Statistical, Social, and Economic Research
kg	kilogram
km	kilometer
MIDC	Metal Industries Development Centre
MONOMEROS	Monomeros Colombo Venezolanos, S.A.
nBTPT	N-(n-butyl) thiophosphoric triamide
NifTAL	Biological Nitrogen Fixation Technologies for International Development
NMI	Nederlands Meststoffen Instituut
OAU	Organization of African Unity
PAPR	partially acidulated phosphate rock
PPI	Phosphate and Potash Institute
PR	phosphate rock
RAE	relative agronomic effectiveness
SADCC	Southern African Development Coordinating Conference
SFRP	Soil Fertility Restoration Project
SOCOADA	Sociedad Cooperativa del Distrito de Altar S.C.L.
SQM	Sociedad Quimica y Minera de Chile, S.A.
SSP	single superphosphate
t	tons
TFI	The Fertilizer Institute
TPR	Tahoua phosphate rock
tpy	tons per year
TSP	triple superphosphate
TSPS	sulfur-fortified triple superphosphate
UNDP	United Nations Development Programme
UNIDO	United Nations Industrial Development Organization
USAID	U.S. Agency for International Development
USDA	U.S. Department of Agriculture
WAFMEN	West African Fertilizer Management and Evaluation Network
WSR	wet-seeded rice

International Fertilizer Development Center
P.O. Box 2040
Muscle Shoals, Alabama 35662 U.S.A.

Phone: 205-381-6600
TWX-810-731-3970 IFDEC MCHL
Telefax: 205-381-7408

ISSN-0748-5875

Editing, Marie K. Thompson/Typing, Word Processing Center/Layout and Graphics, James C. Starkey/
Cover Design, Terry L. McGee/Cover Photo, Charles E. Butler.