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INTERNATIONAL FERTILIZER DEVELOPMENT CENTER

ANNUAL REPORT 1990

"Entering the Age of Global Ecological Interdependence"

IFDC *Profile*

International Fertilizer Development Center: *A Profile*

"World peace will not be built on empty stomachs. Deny farmers today the use of commercial fertilizers and other chemical aids and the world will be doomed—not from poisoning, as some say, but from starvation."

Dr. Norman E. Borlaug, 1990
1970 Nobel Peace Prize Laureate

Toward Sustainable Agriculture

Age-old questions are now being asked but with a greater sense of urgency than in the past. Can a better balance be struck between man and nature? Can the downward spiral of poverty leading to land degradation be reversed? Can the earth's natural resource base sustain the growing demands being hurled its way? Can developing nations find ways to adequately feed their growing populations, which, the United Nations now predicts, will comprise 94% of the expected world increase by the year 2000?

Fertilizers-Securing the Resource Base for Agriculture

Ironically, for many of the developing countries, part of the answer to their dilemma lies hidden deep beneath the earth itself. The cruel cycle of poverty can be broken by taking from the earth natural resources, such as agrominerals—phosphate rock, sulfur, potash, and other essential plant nutrients—to produce fertilizers and then returning these valuable nutrients to the earth to replenish and restore the fertility of the soil and thereby make it more productive.

Thus, the basis for establishing a sustainable agriculture is the soil itself, which contains the nutrients and water that are essential for plant growth. Soil nutrient levels are depleted through direct uptake by crops and their removal from fields and through soil erosion. There is a continual need to replace nutrients and restore the fertility and productive potential of soils. Developing-country farmers must increase fertilizer use on the most productive areas to sustain productivity and minimize and/or avert the need to clear and cultivate marginal lands.

In many tropical and subtropical countries, the amount of land that can be brought into cultivation is limited. Those areas that can be used for growing crops need both organic and inorganic sources of nutrients to maintain their yield potential because the soils of most of these areas are so infertile. Furthermore, high-yielding crop varieties are nutrient-use intensive and without adequate soil fertility they produce yields no higher than traditional varieties. It is generally agreed that high-yielding varieties were the stimulus for the green revolution, but without fertilizer this revolution would not have taken place. A study by the International Rice Research Institute (IRRI) has shown that fertilizers accounted for at least 50% of the yield increases achieved during the green revolution. Similarly, the Food and Agriculture Organization of the United Nations has estimated that 47% of the potential increases in global production to the year 2000 must come from fertilizers.

Combatting Poverty

Fertilizers play an important role in generating employment and income in rural areas and in saving and earning foreign exchange at the national level. Increased demand for fertilizer allows many developing countries to use their indigenous resources for fertilizer production for domestic purposes and exports.

Fertilizer use, in terms of kilograms per hectare of arable land and land in permanent crops, is lower in most of the developing countries than in the developed countries. In fact, sub-Saharan Africa uses only about 9 kilograms of fertilizer nutrients per hectare; Latin America uses 49 kilograms per hectare; and Asia uses 115 kilograms per hectare (1988). In contrast, fertilizer use in North America and Europe is 85 kilograms per hectare and 225 kilograms per hectare, respectively. Because of their low use levels, there is great potential for most developing countries to increase food production and, at the same time, improve the environment through the effective and efficient use of fertilizers.

IFDC's Impact

IFDC has achieved an impact in these areas:

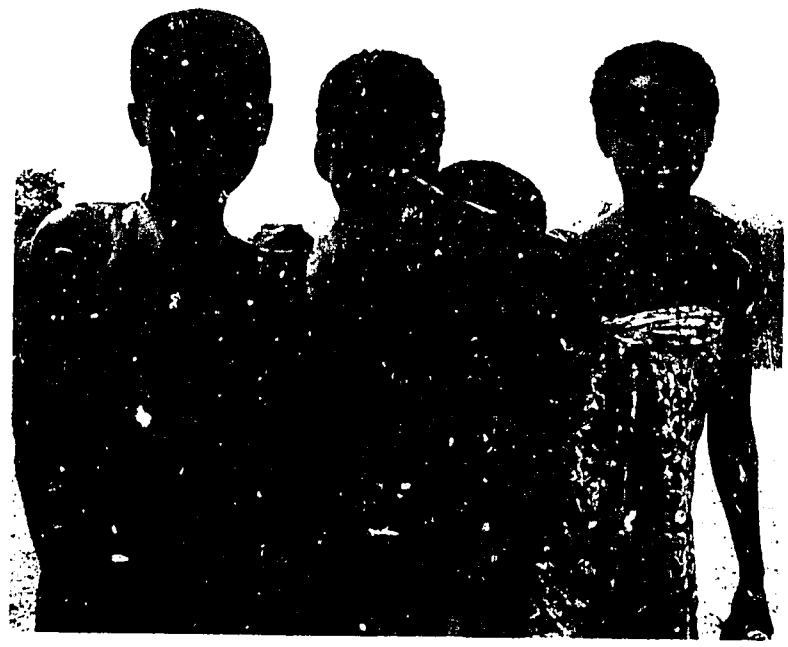
- It has helped several developing countries find ways to use their indigenous phosphate resources as plant nutrients. Examples include Brazil, Colombia, India, Mali, Philippines, Tanzania, Venezuela, and Zambia.
- By promoting a free and competitive marketing system for fertilizers in Bangladesh, IFDC has increased the efficiency of that system and saved money for the country and its farmers. The Bangladesh experience may serve as a model for others to consider.
- Its scientists have identified the pathways, quantified the losses from nitrogen applied to rice and other crops, and devised means to curb those losses, thus conserving resources and preventing environmental pollution.
- Its economists, systems modelers, and soil scientists have developed and incorporated nutrient components into major crop models that add materially to the accuracy of prediction of crop and treatment interactions without requiring further expensive field experiments.
- Its scientists have developed a new soil testing technique to determine the amount of phosphorus in the soil that is available for plant use. This new technique, which is simple, inexpensive, and accurate, is being tested in the developing countries and the United States.
- It has trained more than 4,000 people from more than 100 countries.
- It has provided technical assistance to more than 80 countries through its problem-solving approach.
- "The Center has become a very significant force in the improvement of national agricultural policies of developing countries."—the late Sir John Crawford

Averting Environmental Degradation

Deforestation, desertification, salinization, and soil erosion represent serious environmental problems in many developing countries, especially in Africa and Latin America. The increased use of organic and inorganic fertilizers in conjunction with other complementary inputs can assist in reducing environmental problems by raising the productivity of cultivable land and thereby reducing pressures on marginal lands that are susceptible to desertification and soil erosion. Providing balanced nutrition for higher yields on cultivated areas can help protect forests because the need to clear further forests for cultivation will be reduced. It is increasingly recognized that the development of sustainable food production to meet the projected food needs of the developing countries will be critically dependent on the use of inorganic fertilizers to build or maintain soil fertility. Nobel laureate Dr. Norman Borlaug (1990) says that "Given current scientific knowledge, it is my belief that the judicious use of agricultural chemicals—especially chemical fertilizers—is absolutely essential to produce the food needed to feed today's population of 5.3 billion, which is currently increasing at the rate of 88 million per year."

In fact, IFDC scientists believe that the reduction or elimination of fertilizer use would result in increased environmental degradation through acceleration in the rates of deforestation, soil erosion, and desertification, as evidenced in recent years in sub-Saharan Africa, the region of the world with the lowest use of fertilizers. In many agricultural regions of developing countries, the real economic and social benefits of fertilizer use significantly outweigh the potential and often avoidable adverse effects.

A sustainable, environmentally safe agriculture can become a reality, provided the necessary policies, strategies, and programs are implemented to increase food production in the developing countries. Sustainable agriculture, according to the Technical Advisory Committee (TAC) of the Consultative Group on International Agricultural Research (CGIAR), should involve the "successful management of resources for agriculture to satisfy the changing human needs while maintaining or enhancing the quality of the environment and conserving natural resources."



These Togolese children aspire to a secure, prosperous future. IFDC's efforts in human resource development in Africa focus on helping Africa's institutions and its people to meet their needs and aspirations.

The Role of IFDC

Working in concert with the other international agricultural research centers (IARCs) and the national agricultural research systems (NARS), IFDC is committed to protecting the earth's natural resource base and helping to increase crop production in the developing countries. Since its inception the Center has concentrated on increasing food production with a sustainable perspective in its work in Africa, Asia, and Latin America even before sustainability was considered essential to long-term agricultural development. Since 1975 IFDC's scientists have been striving to create a more sustainable agriculture in the developing countries by helping them to use their indigenous resources to produce the fertilizers needed to build soil fertility and produce more food. The Center's scientists have developed new ways to increase the efficiency of fertilizer by reducing losses of nitrogen and thereby limiting or eliminating its contamination of the atmosphere and groundwater. IFDC has focused its efforts on environmentally sound phosphate research in that it has concentrated on taking from the earth an indigenous resource (phosphate rock), exposing it to minimum processing, and returning it to cultivated areas of the earth as fertilizer. Future research involving other important nutrients, as well as multinutrient products, will emphasize sustainable soil fertility management and promote the use of organic and inorganic sources of plant nutrients that are available in the specific agroecological zones. IFDC has joined forces with national collaborators to develop the human resources needed to effectively and efficiently carry out the many functions of the fertilizer sector. The Center has always stressed the need for efficiency in the production, marketing, and use of fertilizer to ensure cost-effectiveness. The synergistic partnerships that IFDC's leaders have developed with scientists, policymakers, and extension workers of developing countries have helped to keep the Center's technology responsive to the changing needs of people in developing countries. The Center tests and adapts its technology to fit the socioeconomic, cultural, and ecological conditions of the developing countries where it is designed to be used.

IFDC: *Facts and Figures*

The Center's Origin and Its Mission

The world food crisis of the early 1970s provided the impetus for the creation of an international fertilizer research center to focus on the development of appropriate fertilizer technology and related knowledge to increase food production in the developing countries, especially those of the tropics and subtropics. The U.S. Secretary of State in a speech before the United Nations General Assembly in April 1974 urged the establishment of this center. On October 7, 1974, IFDC was officially registered in the State of Alabama as a private, nonprofit corporation. On March 14, 1977, IFDC was designated a nonprofit, public international organization.

IFDC's Board of Directors

IFDC is governed by a Board of Directors that is fully international and was established in accordance with standards set by the CGIAR. The members of the Board bring together a wide range of scientific and management expertise. The IFDC Board is currently composed of five members from developing countries, three from the United States, and three from other developed countries.

IFDC's Program Priorities for the 1990s

- Nutrient Dynamics and Agroecosystems
- Nutrient Characterization and Production
- Information Management Systems
- Economics and Policy
- Human Resources Development
- Agribusiness
- Environmental Assessment
- Project Analysis and Assistance

The Funding Base

Planning funds to establish IFDC came from the United States Agency for International Development (USAID) and the International Development Research Centre (IDRC) of Canada. In addition to the continuing support of these two organizations, funds for training, technical assistance, and research and development come from a wide range of national and international agencies, private foundations, and national governments. Other donors of IFDC now include the Kellogg Foundation; Rockefeller Foundation; World Bank; Directoraat Generaal voor Internationale Samenwerking (DGIS), Netherlands; Der Bundesminister für Wirtschaftliche Zusammenarbeit (BMZ), Germany; Research Institute for Tropical Agriculture (IRAT), France; and the United Nations Development Programme (UNDP).

Location

The Headquarters of IFDC is located in Muscle Shoals, Alabama. Its proximity to the Tennessee Valley Authority's (TVA) National Fertilizer and Environmental Research Center (NFERC) facilitates a sharing of research information and a comprehensive fertilizer research library. In 1987 with assistance from the Government of Togo, IFDC established an Africa Division in West Africa to provide onsite attention to the special problems of the fertilizer sectors of the sub-Saharan region. In addition to the Lomé, Togo, facility, IFDC has entered into an agreement with the Organization of African Unity to manage the African Centre for Fertilizer Development (ACFD) in Harare, Zimbabwe, initially for a period of 5 years.

Staff

Because it is composed of an international, multidisciplinary, multilingual staff and is not affiliated with any specific government or commercial interests, IFDC can provide an unbiased opinion regarding most facets of fertilizer sector development. Recruited from more than 20 countries, the IFDC staff is both internationally and technically diverse with almost one-half of the total being agronomists, chemical engineers, chemists, economists, geologists, marketing specialists, sociologists, and soil scientists. IFDC is able to conduct well-focused fertilizer research and development because of three complementary factors: (1) the ability to use its multidisciplinary teams for project planning and implementation; (2) the ability to produce and test experimental fertilizers in laboratories, pilot plants, greenhouses, and experiment stations and fields in the developing countries; and (3) linkages with research and development institutions around the world. IFDC has participated in a wide range of projects in collaboration with national/international food and agricultural organizations; financial institutions; agricultural research stations; environmental groups; manufacturers and associations; and research and development agencies.

Organization

The three divisions located at IFDC Headquarters are Resources Management Research and Development, Outreach, and Administration. The Center's organizational structure provides for project teams organized across program lines. The eight program areas include: nutrient characterization and production, nutrient dynamics and agroecosystems, information management systems, economics and policy, agribusiness, environmental assessment, human resources development, and project analysis and assistance. The Office of the President coordinates fund-raising activities and is in charge of general management of the Headquarters and overseas operations. (The programs of IFDC's regional office, the IFDC-Africa Division, located in Lomé, Togo, are discussed in a later section.)

The Center's Facilities

The Center's facilities include laboratories; greenhouses; growth chambers; specialized instruments essential for laboratory research; bench-scale and pilot-plant units used in studies such as beneficiation of ores, acidulation, and granulation of fertilizers; a word processing center and graphics unit; and a library.

Primary Directions for IFDC in the 1990s

During the 1990s IFDC will aim to:

* Further its integrated nitrogen research involving the effective management of native soil nitrogen, biologically fixed nitrogen from legumes, nitrogen from crop residues and green manures, and fertilizer nitrogen.

* Promote its agribusiness activity of which fertilizer is the backbone in a delivery system that provides a range of inputs needed by the farmer—seeds, irrigation, plant protection chemicals, fertilizers, and the necessary technical information.

* Combine nutrient supply with fertilizers and other inputs to yield a sustainable system of land and resource management where nutrients and other inputs are managed with soil and water in the overall crop production plan.

* Increase its interaction with private, public, international, and national institutions to help developing-country farmers achieve a better economic standard of living.

* Intensify its strategic research on sustainability issues.

* Increase its activity in the economic and policy areas.

Improved crop varieties represent an important link in the chain of sustainable agriculture. However, without appropriate types and quantities of plant nutrients, increased yields are impossible.

IFDC's Program Strategy

IFDC's programs concentrate on eight broad areas—nutrient characterization and production, nutrient dynamics and agroecosystems, information management systems, economics and policy, agribusiness, environmental assessment, human resources development, and project analysis and assistance.

Nutrient Characterization and Production Program—specializes in the research and development of both inorganic and organic plant nutrients.

Nutrient Dynamics and Agroecosystems Program—improves or maintains crop production in diverse cropping systems in a sustainable and environmentally acceptable way through the removal or reduction of soil fertility constraints.

Information Management Systems Program—provides, analyzes, and interprets information on the effective operation of an integrated nutrient supply and use system for use by researchers and clients at field, farm, regional, national, and global levels.

Economics and Policy Program—conducts analyses and research in economics, socioeconomics, and policy at the micro and macro levels.

Agribusiness Program—provides developing countries with technical assistance on cost-effective, environmentally sound supply and efficient marketing and use of agricultural materials.

Environmental Assessment Program—keeps under surveillance the systems for production and use of plant nutrients to ensure that food production and environmental protection are attainable and sustainable.

Human Resources Development Program—focuses on the development of a cadre of personnel with emphasis on the production, marketing, and use of nutrients to support agricultural production.

Project Analysis and Assistance Program—provides technical and economic assessment of new projects and institutions that emerge to sustain agriculture.

Special Focus on Africa

Because of the severity of Africa's agricultural problems, IFDC has strengthened its programs in that region during the past few years. With a primary focus on the special needs of the sub-Saharan countries of West Africa, the IFDC-Africa Division located in Lomé, Togo, is involved in activities in the following areas: information management systems, economics and policy, evaluation of indigenous agrominerals, collection and dissemination of fertilizer market information, and regional collaboration and training. In late 1990 IFDC's activities in Africa took on a new dimension. The African Centre for Fertilizer Development was opened in Harare, Zimbabwe. This independent center will be managed by IFDC for at least 5 years.

IFDC's Linkages with Other Organizations

To help carry out its mission, IFDC cooperates with many other international, regional, and national institutions; 25 of its staff specialists are currently outposted in Asia, Africa, and Latin America. The location of scientists worldwide allows technology developed by IFDC scientists and engineers to be tested under a wide range of conditions before its applicability is established for specific areas.

Global Environmental Issues

Environmental issues will command widespread attention throughout the 1990s and well into the next century. The primary issues involved include possible global warming; the deforestation, desertification, and erosion of land in the developing countries; the pollution of air and water; and the increasing shortage of arable land.

By increasing the use efficiency of fertilizer nitrogen, IFDC is developing ways to control the losses of nitrogen to the air, groundwater, and streams, thus preventing pollution. The increased use of organic and inorganic fertilizers along with other complementary inputs can assist in reducing environmental problems by raising the productivity of cultivable land and thereby reducing pressures on marginal lands that are susceptible to desertification and soil erosion. Providing balanced nutrition for higher yields on cultivated areas can help protect forests because the need to clear further forests for cultivation will be reduced. It is increasingly recognized that the development of sustainable food production to meet the projected food needs of the developing countries will be critically dependent on the use of inorganic fertilizers to build or maintain soil fertility.

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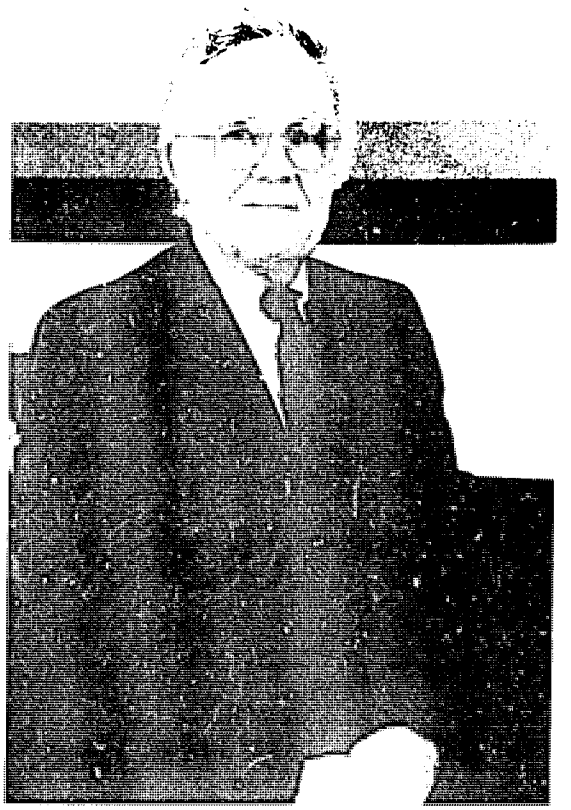
Children in developing countries must spend much of their time working to help their families. These young Nigerien girls are carrying containers of water.

President's Letter



Dr. Paul J. Stangel
IFDC President and
Chief Executive Officer

As IFDC enters the decade of the 1990s, it is confronted with a world experiencing a period of exciting technological innovation, unprecedented economic opportunities, and surprising political reform. This decade will be like none other because it will culminate with the year 2000.

That magical number is having a profound impact on all of us; it is accelerating change and causing us to reexamine everything we do—our values—our institutions.

The 1990s are presenting a new view of the world. A new era of globalization is underway. Shaping this decade is an international call to environmentalism. Communist countries are experimenting with democracy. Even in the poorest nations of Africa, deregulation and privatization are on the ascent. There is a new-found respect for individual freedom and the human spirit.

As we enter this unprecedented period of accelerated change, we will undoubtedly be confronted with enormous challenges. Environmental considerations continue to arouse global concern: the greenhouse effect, the destruction of the forests, desertification, and soil erosion. But there is a growing consensus around the globe that we must work together if we are to solve our environmental problems and sustain agricultural production.

IFDC is prepared to meet this challenge and is actively forging partnerships with national and other international organizations around the world to tackle the challenges of agricultural sustainability and environmentally sound development in the developing countries. As we do so, we are refocusing our efforts to increase agricultural productivity on a sustainable basis in the tropics and subtropics through the transfer of appropriate and environmentally sound technology involving all aspects of fertilizer production, marketing, and use.

We are continuing to focus on problems in ecological zones of three geographical areas: Asia, Africa, and Latin America. Our staff members posted in these areas are becoming increasingly better equipped to solve the agricultural and development problems that they encounter. In addition, they are well versed in the languages, customs, and institutions of their respective host countries. Thus, they bring a cultural awareness to the decision-making process.

In the words of Dr. Nyle Brady, Senior Consultant to the United Nations Development Programme, IFDC is pursuing a "marriage of its traditional programs with new programs relating to the environment

and sustainable agriculture." This move was also supported by Ambassador Blake, Chairman of the Global Committee on Sustainable Agriculture. IFDC's program priorities for the 1990s reflect this reshaping of its efforts and will include the following: nutrient dynamics and agroecosystems; nutrient characterization and production; environmental assessment; information management systems; economics and policy; human resource development; project analysis and assistance; and agribusiness.

"Progress is impossible without change; and those who cannot change their minds cannot change anything."

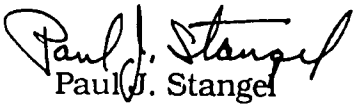
George Bernard Shaw

More specifically, during the 1990s IFDC will aim to further its program on integrated nitrogen research involving the effective management of native soil nitrogen, biologically fixed nitrogen from legumes, nitrogen from crop residues and green manures, and fertilizer nitrogen. Further, IFDC will promote its agribusiness activity of which fertilizer is the backbone of a delivery system that provides a range of inputs needed by the farmer—seeds, irrigation, pesticides, fertilizers, and the necessary technical information.

Additionally, the Center will combine fertilizer and nutrient supply into a sustainable system of land management where they are used effectively with soil and water. To help us achieve our goals, we will increase our interaction with private, public, international, and national institutions to help developing-country farmers achieve a better economic standard of living. At the same time, we will intensify our strategic research on sustainability issues and increase our activity in the economic and policy areas.

Thus, our new directions will provide a sharper focus to help us meet the challenges created by the rapid changes of this decade. Specifically, as change accelerates during the 1990s, five interrelated issues will increase in importance: producing and introducing environmentally sound fertilizer products and nutrient management practices for sustainable agriculture, promoting the use of indigenous nutrient resources, developing and transferring fertilizer and plant nutrient strategies for sustainable agricultural systems, developing human resources, and encouraging fertilizer and nutrient management policies for agricultural production. For several years, we have focused on segments of these challenges. The articles that follow relate our perception and evaluation of the problems confronted by developing countries and our approaches and proposed solutions to them. These articles only propose to give brief highlights of our progress; they do not constitute comprehensive reports of our activities. However, the articles should give you a clear impression of the magnitude and direction of IFDC's change in focus.

As we look to the future, we welcome the changes it may bring for we know there can be no improvement without change.



Paul J. Stangel

Donald L. McCune

IFDC's creator and first Managing Director, Dr. Donald L. McCune, marked another milestone in his 39-year professional career when he retired on January 31, 1990.

Throughout his more than 15 years as IFDC's Managing Director, McCune guided the Center as it helped to serve the fertilizer needs of the developing countries. Under his directorship, IFDC trained more than 3,000 people from approximately 100 countries in fertilizer production, marketing, and use; introduced new technologies and concepts of using indigenous phosphate mineral deposits; and found ways to improve fertilizer efficiency.

By talking with some of the Ohio native's long-time colleagues, one can gain insight into the reason for the successes of McCune's career. The late Travis P. Hignett, former Special Consultant to the Managing Director, once summed up McCune's personality well.

Dr. Donald L. McCune
IFDC's Founder and
First Managing Director

"Dr. McCune always exhibited a contagious enthusiasm, which he translated into vigorous action," Hignett said. "He always had some project that he was excited about and usually for a good reason."

Throughout his tenure as IFDC's Managing Director, McCune was a catalyst for change. As Hignett said, "He didn't necessarily tell people what or how to do something, he told them what the problem was. Once an employee was impressed with the importance of the work, he was inspired to do the work and derive a plausible solution. Dr. McCune's greatest strength was that he always inspired people to do their very best."

McCune's creative character was exemplified early in his career in the roles that he played in successfully developing experiment stations in Indiana (U.S.A.) and Chile during the 1950s, in creating and directing an international staff for the National Fertilizer Development Center (now called the National Fertilizer and Environmental Research Center)of the Tennessee Valley Authority during the 1960s, and in developing and directing IFDC from 1974 to 1990.

The effectiveness of his organization's activities can be observed in countries such as Bangladesh, Brazil, Colombia, India, Mali, and Venezuela, to name a few. These countries have received technical assistance in determining methods of using their natural resources in fertilizer production and identifying management practices designed to improve fertilizer efficiency. Many are now capable of meeting their fertilizer needs from local production.

In the final analysis, the effectiveness of McCune's work is manifested in the stature that IFDC and its multidisciplinary staff have attained as a valuable source of impartial information on international fertilizer research and development.

In McCune's words, "IFDC's clients in the developing countries accept and trust the Center's specialists and rely on their judgment as honest brokers."

Educated as an agronomist and plant physiologist at Ohio State and Purdue universities, McCune received a U.S. Public Service Award from the American Society for Public Administration and the National Academy of Public Administration in 1986. In 1981 he received the Fertiliser Society's Twelfth Francis New Memorial Award.

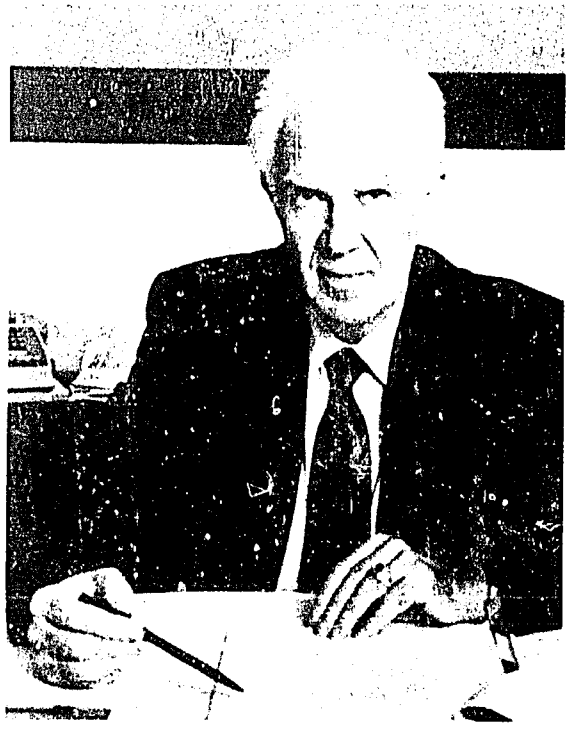
According to McCune, "The bottom line is that your impact is only effective and permanent if you have trained people." This statement exemplifies his legacy to the Center because he trained others to take his place when he stepped aside on January 31, 1990.

His successors at IFDC face a number of challenges into the next decade, according to McCune. Some include the increasing environmental concerns and the continued effort to feed more hungry residents of the world's developing countries. IFDC's mission is far from complete. The impact of Dr. McCune's foresight will be felt in the developing world well into the 21st century.

David B. Parbery

On February 1, 1990, Dr. David B. Parbery began his short tenure as IFDC's second Managing Director. Eight months later, on October 5, 1990, the IFDC Board of Directors relieved Dr. Parbery of his duties for health reasons. At that time, two new positions were established, namely, the positions of President and Chief Executive Officer, filled by Dr. Paul J. Stangel, and Executive Vice President and Chief Operating Officer, Dr. Amit H. Roy.

Even though his tenure was short, Dr. Parbery has left his mark on IFDC. He encouraged the staff to look at fertilizer as part of a total nutrient management system. He also emphasized the need for addressing the environmental issues. Many of these initiatives are now being developed by IFDC management and staff.



Dr. David B. Parbery
IFDC's Second Managing Director

An international development specialist from Australia, Dr. Parbery has had an outstanding career, spanning a period of some 37 years. This career has covered a broad spectrum of experience, ranging from research scientist to director of international development with several organizations.

Parbery has lived and worked in the United States for approximately 15 years (on an intermittent basis) and approximately 7 years in Asia. Throughout his professional life, he has worked in 20 countries.

The Australian native "likes initiating things, enjoys innovation, and takes pleasure in seeing new ideas coming to fruition."

Prior to his appointment as IFDC's chief executive, Parbery was Managing Director of Luminis Pty., Ltd., the technology transfer company of the University of Adelaide, Australia, for 5 years. At Luminis, he was highly successful in commercializing a varied range of technology developed by the University of Adelaide. The range of specialties covered the fields of agriculture, the physical and biological sciences (especially medicine and dentistry), and engineering.

Prior to that appointment, he served in various capacities with the World Bank in Asia and Latin America for more than a decade.

Preceding this period, he founded and/or served as the managing director of three other organizations: the Agricultural and Industrial Development Corporation, Ltd., the Kalbilli Pastoral Co. Pty. Ltd., and the Australian Potash Research Institute—all of which were headquartered in Canberra, Australia.

Having first been educated in Australia, where he received a B.S. degree in biology at Sydney University, Parbery ventured to the United States for the remainder of his education. At the University of Missouri, he completed an M.S. degree in agronomy, and at Cornell University he received a Ph.D. in agronomy and development economics.

Producing and Introducing Environmentally Sound Fertilizer Products and Nutrient Management Practices

Many people of the developed world perceive fertilizer as a contributor to major environmental problems—groundwater pollution, surface water enrichment, and greenhouse gas emissions. Even though fertilizers can be contributors to these problems, particularly when overly used or misused, these same fertilizers have allowed the developed countries to produce surplus amounts of high-quality food. The poor countries, however, face very severe food deficits and most of the world's projected population growth will occur in these countries, which even now cannot provide enough food for themselves. To them, environmental problems are often secondary to immediate needs for food. Despite these conditions, IFDC seeks means to prevent fertilizers from causing pollution and to reduce damage to the environment by correct use of fertilizers.

Presently water pollution due to fertilizer use in the developing countries is not serious because they use such low amounts of fertilizers. A possible exception may be irrigated areas with sandy soils such as in the Punjab in India where fertilizer use is high. Scientists at IFDC continue to research fertilizer practices that reduce pollution of water and the atmosphere. By achieving higher uptake of nutrients by the fertilized plants, the scientists minimize pollution problems.

IFDC is broadening its focus to include the creation of sustainable agricultural productivity and food production in the tropics and subtropics through the development and use of improved and environmentally sound fertilizers and fertilization practices. In 1990 we saw progress from our efforts and the Center's increased attention on environmental issues.

"Conservation is a state of harmony between men and land."

Aldo Leopold

USG Agrotechnology

Our developments in urea supergranule (USG) agrotechnology provide some solutions to the food production problems of millions of small-scale, economically constrained rice farmers in rainfed areas of south and southeast Asia. In the mid-1970s IFDC proposed the use of USG to facilitate effective deep-point placement of urea in flooded rice soils that are highly prone to nitrogen losses. Since then IFDC and several national as well as international institutions have demonstrated the potential of properly deep-placed USG for nearly eliminating losses of urea-nitrogen (except leaching) and increasing grain yields of transplanted rice. For Boro paddy in 1990, 110 USG demonstrations on farmers' fields were carried out in 16 regions of Bangladesh. On an average, Bangladeshi farmers using 80 kilograms of nitrogen per hectare harvested 852 kilograms more paddy per hectare (16% increase) for deep-placed USG than for split-broadcast prilled urea.

An Indian farm worker uses the IFDC-developed urea-briquette applicator to deep place urea briquettes. Developing-country farmers are receptive to appropriate, affordable management practices that can help them increase their yields and save labor.

Sustainable Technology for the Economically Disadvantaged Small Farmer

From agroclimatic and socioeconomic considerations, the most appropriate clientele for USG use is the small-scale, economically disadvantaged rice farmers in rainfed areas. Even today, these rice farmers use animal-drawn implements or hand tools for land preparation. They either apply no fertilizer or inadequate amounts inefficiently. As a consequence of the traditional methods of cultivation, their rice yields are very low (1-2 tons per hectare) year after year.

IFDC scientists therefore are developing an appropriate USG agrotechnology that will enable the small rice farmers to use the product efficiently for obtaining additional yields with minimal risk while practicing sustainable rice cultivation in rainfed areas. The USG agrotechnology consists of (1) a production and supply scheme of the right size (weight) USG at an affordable price and (2) the use of an appropriate method of deep placement of USG by hand or machine that will ensure an additional yield (600+ kilograms per hectare) to 90% of potential USG-user farmers.

At present, IFDC is testing its village-level briquetter for extended periods to determine its endurance and to ascertain if any further improvements are needed before making this urea briquette production technology available outside IFDC.

Many small rice farmers like those in Bangladesh who practice transplanting in line but only in one direction are able to effectively deep place USG by hand. Other clientele farmers in India and other countries still practice random transplanting mainly due to economic constraints, and they cannot use USG effectively. To eliminate this problem, IFDC researchers, in collaboration with the Konkan Krishi Vidyapeeth (KKV) in Dapoli, Maharashtra, India, have developed a simple bamboo transplanting guide that simplifies line transplanting and requires only one or two workers to use it.

The results of 1990 field trials conducted in collaboration with KKV suggest that, in general, additional grain yields of up to 1.5 tons per hectare at 60 kilograms of nitrogen per hectare were obtained with lower plant population as compared with the farmers' transplanting method. By using the transplanting guide, Maharashtrian rice farmers and others like them can save expensive seed (up to 30%) and therefore eventually realize up to a one-third saving in all other subsequent inputs required for seedling preparation, uprooting, etc. The farmers may therefore also proportionately save labor

required for transplanting. In other words, the overall savings in seed and labor could help the farmers to partly offset the high labor cost required for USG placement. In addition, the use of the transplanting guide for line transplanting with modified spacing provides "traffic lanes" for performing all post-transplanting operations efficiently. Because the farmers are able to control plant population, they can hope to realize yield potentials of high-yielding varieties (HYVs).

A collaborative field trial conducted by PhilRice during the 1990 dry season at Maligaya, Nueva Ecija, Philippines, has confirmed the satisfactory operation of the IFDC-developed PVC urea briquette applicator. The yields of transplanted rice for the applicator-placed and hand-placed urea briquettes were the same, and the yield for the applicator-placed urea briquettes at 63 kilograms of nitrogen per hectare was superior when compared with the farmers' split-applied prilled urea at both 63 kilograms and 90 kilograms of nitrogen per hectare.

To make the USG use part of the sustainable rice-farming system that the small farmers can afford in rainfed areas, IFDC scientists in collaboration with KKV evaluated deep-placed USG with limited gliricidia green manuring, an agroforestry approach. The results of the collaborative field trials suggest that the additional yields due to deep-placed USG (up to 54 kilograms of nitrogen per hectare) were improved or ensured by limited gliricidia manuring at 2 tons of loppings per hectare as compared with the same nitrogen rate applied as prilled urea with limited gliricidia manuring.

For increasing or ensuring efficiency of urea-nitrogen, the rice farmers will have to use small affordable doses of phosphate fertilizers in combination with USG. The results of IFDC/KKV collaborative field trials conducted on farmers' fields during 1990 Kharif (wet) season suggest that the deep placement of USG containing diammonium phosphate (USG-DAP) can be an agronomically efficient as well as environmentally sound management practice in transplanted rice especially when rice is transplanted with modified spacing on lateritic soils with high phosphorus-fixing capacity. The use of USG-DAP can significantly increase yields as compared with conventional applications of single superphosphate plus prilled urea and can eliminate runoff losses of applied nitrogen and phosphorus, thus protecting the environment.

In short, the developments in USG agrotechnology are based on an integrated nutrient management approach and aim at environmentally sound, sustainable rainfed transplanted rice farming.

Integrated Nutrient Management

IFDC scientists are fitting fertilizer into an integrated nutrient management system where fertilizer is viewed as a supplement to nutrient sources derived from the soil, animal manure, urban wastes, crop residues, and other sources. In research being conducted jointly with IRRI in the

These Indian women are using simple spacing guides for transplanting seedlings of rice, an important food source for their country.

"One must care about a world one will not see."

Bertrand Russell

Philippines, IFDC is practicing integrated nitrogen management by effectively managing native soil nitrogen, biologically fixed nitrogen from legumes, nitrogen from crop residues and green manures, and fertilizer nitrogen. By so doing, it is lowering the requirements of supplemental nitrogen fertilizer and with proper overall management may reduce the potential for environmental pollution.

IFDC and IRRI scientists have learned that proper placement of urea fertilizer, effective fertilizer timing, and controlled nitrogen release offer the greatest opportunity for improving nitrogen efficiency and overcoming losses. Through denitrification research the scientists have discovered that nitrogen losses also occur between cropping seasons. Originally their work focused on only one rice crop followed by a fallow period or an upland crop.

Between the cropping seasons nitrate can form in the soil; the soil is flooded during the rice crop but as it dries out during the fallow and upland cropping period, nitrate is rapidly formed. When the land is prepared for rice cropping by flooding, this nitrate is lost by denitrification and leaching.

IFDC and IRRI scientists have used green manures, legumes, and alternate crop/soil management practices between cropping seasons of rice as means of recycling and conserving soil nitrogen. The strategy that the multidisciplinary team of scientists has used is to effectively use fertilizer nitrogen in combination with the effective management of soil nitrogen and nitrogen from crop residues, green manures, and legumes. Nitrogen (as nitrate) that is taken up by plants such as green manures is recycled when the plant residues are incorporated during land preparation for rice. Additionally, legumes grown either before or after wet-season rice provide a major source of biological nitrogen fixation in rice crops.

The collaborating scientists have found that the nitrogen from added fertilizer is frequently less than 50% of the nitrogen that is taken up by the plant. The remainder is derived from the soil.

IFDC is working closely with IRRI to identify crop and soil management practices in rice-based systems that effectively use native soil fertility, thereby reducing nitrogen fertilizer requirements for rice and reducing the emissions of nitrous oxide, a greenhouse gas formed during denitrification.

Soil Fertility Restoration

In West Africa the Fertilizer Investment for Soil Fertility Restoration Project (SFRP), an applied agronomic and socioeconomic research and development project, is evaluating various nutrient options (including mineral fertilizers, organic residues, and animal manures) and assessing their benefits for the restoration of soil productivity, sustainability of soil fertility, evolution of farming systems and economies of village communities. The project is also assessing the implications of fertilizer use in various farming systems for resource conservation and environmental degradation.

The SFRP is a 5-year project that is being implemented in collaboration with national research and extension personnel in areas of three countries representing various agroecologies in the region—Ghana (humid forest), Niger (semiarid), and Togo (savanna). In each area, IFDC is working with village communities to assess the long-term impact of fertilizers—not just on crop yields—but on the entire local economy and social life of the people.

Two villages in each ecological zone were selected in areas where soils were impoverished in phosphorus—the primary plant nutrient limiting food-crop production in West Africa. Other criteria used to select villages included access to fertilizer distribution outlets, major food crops, and markets for produce. Farmers in experimental villages were provided with fertilizers

(chemical, indigenous mineral materials, and animal manures) for widespread application on cultivated plots. This gave farmers the opportunity to see the benefits of fertilizers in restoring plant nutrients to soils and boosting the yields and output of food crops.

In the second and third years, when village food production is more secure and lower doses of fertilizer are required to maintain production levels per unit area, phosphorus fertilization strategies are restricted to smaller plots under intensive cultivation, while farmers cultivate the greater part of their cropping areas as they wish. Also, through surveys of participating farmers, information is collected and analyzed on how additional crop output can be marketed to generate income for reinvestment in inputs such as improved seeds and fertilizers in subsequent years. The proceeds of the sale of extra output generated as a result of fertilizer use are deposited in a revolving fund to make fertilizer purchase sustainable in future years.

This West African project has shown that fertilizers and partially acidulated Togo phosphate rock have given yield increases of up to 100% more than unfertilized crops in the three test regions. Fertilizer use increases crop biomass significantly. In the Togo savanna, fertilized plots produced up to three times more millet crop residues than unfertilized control plots. Up to 25% of these residues were roots that help to hold the soil together and impede erosion.

The socioeconomic component of the SFRP is very important and is very in-depth and thorough. Comprehensive feedback is obtained continually from participating farmers, and the implications of fertilizer use on farm budgets, household income, and land use patterns at village levels are carefully monitored. By 1989 a total of 850 farm families in the three countries were participating in the project.

The project has also given major impetus to the commitment and resolve of communities to take responsibility and provide for the future well-being of their people. In Niger, for example, 317 out of 338 (94%) farmers who received fertilizers in 1989 cooperatively generated US$28,000 from the sale of surplus produce. This money was put into a communal fund to buy fertilizers for the 1990 cropping season. This has revived the spirit and enthusiasm of farmers to take a more active and collective role in planning and controlling the destinies of themselves and their families; they have organized several community activities in support of the project and to improve their living conditions generally.

This Nigerien woman is one of the beneficiaries of an IFDC project designed to restore the fertility of her country's soil. Millet is one of the primary crops included in this project.

"As the earth's population increases and more land area is used to produce needed food, fuel, and fiber, attention to natural resource conservation becomes even more vital."

Dr. Nyle C. Brady

The Role of Women

Women are also participating actively in the project. Fertilizers were made available to 120 women farmers for their food crop and vegetable farms. For virtually all, this was their first exposure to fertilizers, and many are now committed to their continual use. The capacities of collaborating national research and extension personnel to undertake comparable projects have been developed strongly. In 1990, 63 staff from Ghana, Niger, and Togo benefited from 12 workshops and seminars organized by the project.

The SFRP project is a broadly based research and development project that involves community participation, restoration and maintenance of soil fertility, efficient production and marketing of produce, and the conservation of the resource base for use by future generations.

New Environmental Programs

IFDC is beginning new programs to understand the environmental effect of fertilizers. One of the most severe environmental problems facing poor countries is the loss of soil productivity through soil erosion. Hillsides have had their topsoil eroded by water, and lack of soil cover and organic content causes rapid runoff of water rather than absorption and slowed release of water to rivers. The use of fertilizers to increase food production on the more agriculturally suitable soils in the developing countries could greatly reduce the need to cultivate less productive, marginal lands.

Another way that soil productivity is being greatly decreased in the developing countries is through loss and depletion of nutrients needed by crops. For centuries, man has used the technique of slash-and-burn to rejuvenate soils. This system uses regrowth of remaining natural vegetation to replenish organic matter and to concentrate plant nutrients at the soil surface where they can be used by a cultivated food crop. While a 15- to 20-year regrowth period had been normal in much of the tropics, population demands have progressively shortened this regrowth period to just a few years. Less nutrients and organic matter accumulate for the food crop, thus crop yields of such systems have steadily diminished. IFDC scientists, working with the International Council for Research in Agroforestry (ICRAF), the International Institute of Tropical Agriculture (IITA), and the International Center of Tropical Agriculture (CIAT), and others, are seeking low-cost alternatives to the slash-and-burn system that will replenish nutrients and organic matter to the soil, thus producing a sustainable and more environmentally sound system.

Another environmental concern is the increase of certain naturally occurring gases in the atmosphere that absorb sunlight and thereby heat the atmosphere. The so-called "greenhouse gases," which are of most concern to IFDC researchers, are nitrous oxide, which can originate from nitrogen transformations, and methane, which is produced from inundated rice fields. Nitrous oxide emissions from fertilizers during flooded periods are very low; however, emission is expected to be very high during the dry, off-season, fallow period of rice growth. IFDC scientists are currently measuring nitrous oxide emissions during the dry fallow period.

Methane is a greenhouse gas that is emitted in large quantities from flooded rice soils. The methane originates from organic matter in the soil and from rice plant root exudates and root die-back. The plant source is of major concern because the larger, healthier, and more productive the plant, the more methane that is produced. The processes of methane emission from flooded rice soils are currently poorly understood. In cooperation with IRRI scientists, IFDC researchers are therefore studying the effects of fertilizer applications on methane emissions.

Sustainability is an extremely complex issue, which undoubtedly will continue to be debated for years to come. However, by establishing these projects, IFDC is playing an active role in the realization of environmentally sound sustainable agriculture in the developing countries.

Promoting Use of Indigenous Nutrient Resources

If developing-country food needs are to be met on a sustainable basis, the conservation of the earth's agricultural resources is urgently needed because in many developing countries cultivation has already been extended to marginal lands. These resources must be conserved and enhanced to meet the needs of the world's growing human family, which the United Nations predicts will number 8.5 billion by 2025, almost double the present population. Over the next few decades the global food system must be managed so as to increase food production by 3%-4% yearly. Most of this food must come from increased productivity of lands already under cultivation.

A long-term solution to the problem should be based on more efficient use of plant nutrients, including organic fertilizers. However, without the use of inorganic fertilizer, agricultural production would collapse in many parts of the world; organic fertilizers alone cannot satisfy all of agriculture's nutrient needs. In fact, as Dr. Norman Borlaug has said, "the amount of composted organic animal manure that would be needed to produce 47 million metric nutrient tons of chemical nitrogen (used in one particular year) would be about 3.2 billion tons, were it available. This volume of organic material would require a 2.9-fold increase in the world animal population, with all the additional grain and pasture feeding implications that such an increase would require, in addition to the transportation costs associated with distributing these organic fertilizers with such a low nitrogen concentration."

In many tropical countries, cultivable land is limited. Those areas that can be used to grow crops are highly infertile and need organic and inorganic fertilizers to maintain yield potentials. Without good soil fertility and sound management practices, large quantities of nutrients are lost through soil erosion. Furthermore, harvested crops remove nutrients from the soil and therefore must be continually replaced. Increased use of fertilizers and other inputs on cultivable land to raise its productivity is necessary to avoid cultivation of marginal lands that are susceptible to desertification and soil erosion.

For many of the developing countries, the key to sustainable food production lies beneath the earth itself. By using their natural mineral resources such as phosphate rock to produce fertilizer and returning these valuable nutrients to the earth to restore the soil fertility, they can make their land more productive. Thus, part of the answer to achieving sustainable agriculture is the soil itself, provided essential plant nutrients are maintained at levels needed to sustain plant growth.

Since its inception IFDC has pioneered work on the characterization and effective use of indigenous agrominerals such as phosphate rock. These technologies have been developed first at Headquarters, subsequently tested at other IARCs, and eventually passed to institutions at the national level by using regional networks and national programs.

As a result of efforts by IFDC and others, a major portion of the phosphate used in Brazil is now processed from indigenous deposits. As a further example,

"While we have no choice but to 'use' natural resources, they must be used in such a way that they can continue to be available for future generations."

Joe Wheeler
Director, Programme Integration, United Nations Conference on Environment and Development

"It's not the land itself, that constitutes the farmer's wealth but the mineral nutrients in the soil, which nourish his crops."

Justus von Liebig
"Father of the Fertilizer Industry"

A Colombian farmer and his wife are working in one of IFDC's phosphate experiments. Since the IFDC project is being conducted on their farm, they are reaping the benefits of this collaborative work and improving the quality of their lives.

Indonesia is reconsidering building an additional triple superphosphate plant to serve the phosphate needs for Sumatra and instead will try to use imported ground natural phosphate rock for direct application to supply the phosphate needs of crops grown on acid soils. Successful evaluations done at the farm level were realized and transferred to the manufacturing level. These experiences are now being evaluated in the countries of sub-Saharan Africa and soon will be offered to the farmer primarily due to the initial developmental work done by IFDC.

Approximately 20 sub-Saharan countries have phosphate deposits, at least 10 have natural gas, and others have potash and sulfur resources that potentially can be used to produce a range of fertilizers. Because of the identification of phosphorus as the major nutrient deficiency in large areas of tropical Africa, the development of indigenous phosphate resources to supply nutrients is a major research initiative of IFDC's regional office in Lomé, Togo. Several known deposits of African phosphate rock have been characterized to gauge their potential as fertilizer raw materials. Research is being performed to determine how these ores can be used to provide plant nutrients.

IFDC researchers involved in the Soil Fertility Research Project in West Africa are promoting the use of inorganic fertilizers as well as indigenous materials in whichever agroecology they are available. Thus, phosphate rocks from Niger and Togo are being evaluated in selected villages in these countries on a relatively large scale alongside conventional fertilizers and animal manures. Yield increases in the order of 100% by fertilized maize and millet over unfertilized or unmanured crops have been recorded in the humid zone of Ghana, the savannas of Togo, and the Sahel of Niger.

Fertilization also results in increased crop biomass. This added benefit for maintaining the soil resource base for agriculture is often overlooked in assessing the value of fertilizers. Thus, on trials in Togo, using (1) partially acidulated Togo phosphate rock, urea, and potassium chloride and (2) single superphosphate, urea, and potassium chloride produced increased yields of 225% and 295%, respectively, in millet crop residues over unfertilized plots. The return of these materials to the soil improves its nutrient and organic-matter status. Every ton of millet stover has the potential of supplying about 5 kilograms of nitrogen, 1 kilogram of phosphorus, 15 kilograms of potassium, 450 kilograms of carbon plus various quantities of other nutrients.

On the Latin American continent, IFDC has long been involved in research to find energy-efficient, cost-effective alternatives to the more expensive imported phosphate fertilizers by using natural and altered phosphates from countries like Colombia. During 1990 IFDC scientists, stationed at CIAT in Colombia, continued their research on the residual effect under field conditions of natural finely ground phosphate rocks and partially acidulated phosphate rocks mixed with urea and two potassium sources. The

comparison of the agronomic effectiveness of partially acidulated phosphate rocks from Colombia and Bolivia and of these phosphate rocks compacted with triple superphosphate were extended to include not only beans but also crops such as upland rice in rotation with soybeans and maize.

Generally, additions of low reactive phosphate rocks do not show an immediate effect on crop yields, but with time these phosphate fertilizers start to show positive effects on crop production. This important aspect of phosphate fertilization, necessary to economically evaluate phosphate sources, was studied during 1990.

As a result of IFDC research and promotion of indigenous resources, 16,000 tons of Colombia's Huila phosphate rock (approximately one-seventh of Colombia's annual consumption of phosphate fertilizers) is now being sold and consumed on farmers' fields in that country each year. By using this indigenous fertilizer, Colombia is realizing an estimated savings in foreign exchange of US $640,000 per year.

As a result of the transfer of technology produced by the IFDC Phosphorus Project to Colombian farmers, rice growers in the Eastern Plains are now using 4,000 tons of Huila phosphate rock per year on some 11,000 hectares.

Colombian sugarcane growers have obtained excellent results using Huila phosphate rock. They are consuming approximately 1,000 tons of the indigenous product per year. After applying the product for several years, the Cauca Sugar Company has found that the phosphorus content of their acid soils has increased considerably, and they are now reducing the rates of conventional phosphate fertilizer generally used.

As a consequence of IFDC research in the Eastern Plains of Colombia, farmers are now fertilizing approximately 4,000 hectares of improved pastures with Huila phosphate rock. Their results are excellent and represent important savings in the cost of phosphate fertilization.

After 5 years of research, the Coffee Federation Research Center (CENICAFE) has found that Huila phosphate rock produces the same agronomic effectiveness as do other phosphorus sources such as triple superphosphate, diammonium phosphate, and basic slag. CENICAFE plans to recommend Huila phosphate rock as the least expensive phosphorus source.

The ultimate test for any technology is its acceptance or rejection by the intended users. In the case of Huila phosphate rock, it is gaining many advocates among

Colombian farmer, Roosevel Hernandez, and his family have seen their standard of living improve substantially after using IFDC-developed technology involving the use of indigenous phosphate fertilizer on their farm.

Colombian farmers. For example, Roosevel Hernandez, a Colombian farmer who cultivates a 6-hectare farm, has seen his standard of living improve sharply since he started using Huila phosphate rock on his crops. In the past Hernandez grew crops on his farm only occasionally; instead he worked on other farms doing fencing, construction, and agriculture-related jobs. Initially he had only a few coffee trees, but at the suggestion of the IFDC and CIAT project personnel, he is planting beans, maize, cassava, and some legumes. In the past he fertilized his crops with only organic products such as coffee pulp, animal manure, ashes, and vegetable residues. After the IFDC scientists established one of their experiments on his farm, Hernandez started using the Colombian phosphate rock fertilizer. He is pleased with the increased yields produced by the indigenous phosphate rock, and his family is reaping the rewards as well.

These examples of IFDC's research using indigenous nutrient resources in Africa and Latin America illustrate the fact that the skill and ingenuity are available to meet the challenge of safely producing food and other crops that the developing countries need for survival and economic development. All that is lacking is the will to apply them in a common partnership for survival. Chemical fertilizers can bring major benefits to farmers when they are properly used. Like many other modern techniques for increasing agricultural output, chemical fertilizers can be abused. It is important to bear in mind that they are not harmful in themselves; it is the way they are applied that counts.

IFDC stands ready to assist the developing countries in finding ways to use their indigenous resources to provide the plant nutrients needed to attain the goal of sustainable agriculture.

"Researchers provide the push; industry provides the pull; as a result, something has to happen."

Dr. Samuel C. Muchena
Managing Director
African Centre for Fertilizer Development

Developing and Transferring Fertilizer and Plant Nutrient Strategies for Sustainable Agricultural Systems

In developing sustainable agricultural systems, IFDC scientists must view agriculture from the farmer's perspective. By so doing, they begin to see past specific varieties, inputs, and management practices to the whole farm. The scientists begin to comprehend the complex interactions that exist among the various crop varieties, soils, climatological factors, and even the human beings whose livelihoods are dependent on stable production systems.

IFDC's challenge is to help make agricultural systems in the developing countries both environmentally sound and economically sustainable. Small, developing-country farmers are primarily concerned with survival—feeding their families and increasing their incomes. We must show them how to make their farms more productive and increase their incomes before we can interest them in changing their nutrient management practices. To bring about environmental improvements, we must first make them economically attractive to the developing-country farmers.

One means that IFDC scientists use to develop an understanding of the interactions between the components of sustainable agricultural systems is crop modeling. Crop models that simulate the effects of weather and major biological interactions in agricultural production systems can play an important role in providing appropriate information to decision makers. Such models can readily simulate the effects of soil properties, varieties, and inputs such as fertilizer and irrigation. The response to a particular practice over many years of historical or generated weather can be simulated and the outcome compared with other strategies. Computers can be used to answer a variety of questions that would require years to answer through traditional means of field experimentation.

For several years scientists at IFDC, in collaboration with others from Michigan State University, the University of Florida, the U.S. Department of Agriculture, International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT) and many other research organizations, have been at the forefront of developing crop models suitable for use in developing-country agriculture. These comprehensive models can predict the impacts of such factors as daily weather, soil properties, crop characteristics, and management practices on agricultural production. They can be used to extrapolate research findings from one region to another and, thus, mobilize a vast amount of experimental data.

Crop models have potential for studying various production problems such as land suitability, fertilizer and pest management, irrigation, and yield forecasting. Thus, these models allow the testing of assumptions about the value of economic inputs like water, fertilizers, and pesticides.

IFDC staff members have participated in the development of the fertilizer and soil nutrient components of crop models for barley, maize, millet, wheat, sorghum, and rice. These models are developed in collaboration with national scientists in several countries, including Colombia, India, Malawi, Thailand, Uruguay, and

"The imperatives of technology and organization, not the images of ideology, are what determine the shape of economic society."

John Kenneth Galbraith

Many developing-country farmers avoid adopting innovative practices because they fear risking their families' food supplies. IFDC's systems approach will provide answers to some of their questions and reduce the risks involved in farming.

Venezuela. The models have been tested in many diverse environments, including Australia, Canada, India, Indonesia, Malawi, Mexico, Netherlands, Philippines, Syria, Thailand, United Kingdom, and the United States.

For example, IFDC scientists and their counterparts at the Chitedze Agricultural Research Station in Malawi are validating the CERES maize model in Malawi. The scientists are matching appropriate maize varieties with the agroecological zones of the country under varying management inputs and updating site- and season-specific fertilizer recommendations in the major maize-growing agroecological zones of Malawi. In addition, they are assisting in agronomic evaluations of indigenous fertilizer materials, such as phosphate rock, as alternative sources of nutrients and identifying soil types on which their use may be beneficial. In another activity they are investigating the use of organic manure and crop residues to help identify low-input maize-cropping management practices with minimum impact on the environment. In this work, the researchers hope to answer such questions as "How much fertilizer to apply and when? How much of the applied nitrogen is lost? How much of the nitrogen is taken up by the plant?"

The scientists will then use these soil information data, crop coefficients, and environmental factors to predict crop yield. In the future, they hope to use this model to effectively assist agronomists, soil scientists, and extension workers in choosing management options. For example, the model can be used to determine which maize varieties to plant to optimize maize grain yield on a particular soil type.

By using crop simulation models, IFDC scientists hope to shorten the time between the development of new agricultural technology packages and their application in farmers' fields. However, to do this successfully requires an appreciation of the biological, economic, social, and cultural constraints that impinge on small-farm production systems in the developing countries. One way of attempting to deal with all of these factors is through the use of whole-farm modeling.

IFDC recently added a new dimension to its modeling program; the Center is adding a socioeconomic component to the crop models. In this effort, the scientists are trying to answer the question: "Why do farmers do what they do?" They are investigating how the interaction between a

farmer's social and cultural background and his financial situation determines his farming system.

The long-term goal of this program is to be able to predict the effect of the adoption of a new technology by the farmer. For example, the scientists hope to answer such questions as, "If farmers adopt a new fertilizer management practice, will it clash with their current practices or customs? What would have to be changed in their customs to encourage them to adopt the new practice? If this technology is available, who will adopt it (i.e., what type of farmer)?" When this prototype model is complete, it will be tested in Guatemala first, but it can be modified to fit the situations in other countries and regions.

Crop simulation models can be used to predict yield trends across an entire region. IFDC scientists, in cooperation with their counterparts at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in India, have validated the CERES-Sorghum model in the Indian semi-arid tropics using experimental data over the past 5 years from the region. The model correctly simulated the response of sorghum to nitrogen application in the experiments and correctly predicted that urea-nitrogen would give slightly higher yields than did the nitrate source. Similarly, the model did well in its prediction of total biomass at maturity and total nitrogen uptake by the crop. Once validated the CERES-Sorghum model was used to evaluate long-term fertilizer strategies as affected by the climatic uncertainties and soil diversity. In addition, the CERES-Sorghum model was used to simulate crop growth and fertilizer response over a 25-year period using daily weather data from Pune, India.

Another option that IFDC scientists are using to present spatial data in an easy-to-understand format is a computer programming system called the Geographic Information System (GIS). This system allows the scientists to overlay a soils map for a region with climatic and topographic data of the same area, allowing the preparation of a new "map" that integrates all three types of information. The model is then run on the small sectors of this "map" characterized by a particular soil, climatic, and topographic type. A new map is then prepared that can be designed to easily and clearly show areas of:

1. Potentially poor nutrient efficiency and weak response.
2. Areas where yield response to plant nutrients will be high.
3. Areas where one crop will be better than another crop in terms of grain yield and economic return to the farmer.
4. Areas where risk of loss via ammonia volatilization, denitrification, or leaching are expected to be severe.
5. Areas where fertilizer use will be highly profitable (or unprofitable); this can be achieved by incorporating economic factors, such as crop prices and fertilizer costs to the model and performing wide-ranging economic analyses.

The GIS technique allows planners and policymakers to see the results of complex relationships among the crop, soil, and climate in the form of maps and displays. This permits nontechnical people to use the data generated by the model to make decisions about nutrient recommendations and brings a sense of realism to what could otherwise be a very abstract analysis. Thus, not only can models be more effective after use of GIS, it also allows the communication of the results of analyses in a map form that clearly shows the implications of different sets of crop management strategies.

The linkage of GIS with effective crop models can also be a very valuable tool in the estimation of the regional impact of global climate change on future crop production trends. This could be accomplished by changing the weather data sets and running the crop model in conjunction with the existing soil files. Maps generated in this manner would be very useful for planning sustainable food pro-

"By working with national organizations, IFDC researchers can offer farmers advice on fertilizer use that is based on a thorough knowledge of their agricultural practices, crops, and conditions. This approach allows IFDC to offer advice that is socially compatible with the goals and needs as stated by farmers themselves."

Dr. Thomas P. Thompson
IFDC Rural Sociologist

IFDC's scientists are collaborating with their counterparts around the world to develop and transfer sustainable agricultural systems that will help to feed the people of developing countries and increase their incomes.

duction strategies that could minimize the effects of future changes in the world's weather patterns.

Thus, computer models complement and make more effective the costly and time-consuming field experimentation traditionally used in agricultural research. By using computer simulation models, scientists can generate information to help government planners, extension agents, and farmers make desirable choices. These models will facilitate the transfer of agrotechnology from one place to another; hopefully, they will reduce the time required between the development of that agrotechnology and its application in the developing-country farmers' fields.

"Listening to farmers is recognized by IFDC as a fundamental requirement for the success of our work. The circumstances, conditions, attitudes, and constraints of farmers are always the focus of socio-economic research and are used in other IFDC research—It cannot be otherwise. This approach allows IFDC and national organizations to conduct collaborative research and offer farmers advice on fertilizer use that is meaningful, useful, and appropriate. Listening to farmers is an integral part of my work."

Dr. Thomas P. Thompson
IFDC Rural Sociologist

Developing Human Resources

With the belief that training is an investment in human capital, IFDC is continuing to devote a significant portion of its efforts toward the development of the human resources of developing countries. The Center recognizes that one of its most valuable products is trained people.

Since IFDC's inception one of its main objectives has been to assist in the training of personnel needed in developing countries to produce, market, and use fertilizer. During 1990 the accomplishment of that objective was furthered by the training of 311 people in a total of 26 training events, including 11 group programs, 1 workshop, and 14 individualized offerings. Four programs in fertilizer marketing, two in production, two in sector development, and four in use efficiency were offered during 1990.

Two new programs were offered during 1990. One of these was a workshop on "Urea-Based NPK Plant Design and Operating Alternatives." This 2-week workshop focused on the economic evaluation of urea-based granulation technology compared with ammonia-based NPK and a comparison of methods that can be used for producing NPKs. The delegates were exposed to an overview of the agronomic potential of these types of fertilizers. NPK production was demonstrated in IFDC's pilot plant to show key factors in the operation including the effect of changes in critical process parameters.

The IFDC-Africa Division, in Lomé, Togo, hosted a program in the "Development of Effective Fertilizer Recommendations," which was targeted toward professionals involved in soil fertility, technical assistance, agricultural economics, and production economics. This program was conducted in English with simultaneous translation into French.

The program was aimed at improving the participants' skills in the techniques required to generate, collect, process, analyze, interpret, and report data obtained from fertilizer experiments. Practical concepts for making fertilizer recommendations to farmers were reviewed. Program participants gained an overview of computer models of crop growth and response to fertilizer.

IFDC and its training partners—the ministries of agriculture in developing countries, other international agricultural research centers, universities, nongovernmental organizations, and the commercial sector—are cognizant of the fact that the measure of success in training is how well people are trained and not how many people are trained. Therefore, IFDC is continually soliciting the advice of the beneficiaries of its training programs to improve the course content and implementation of its training curriculum.

The latest impact study of IFDC's training component revealed that the Center's training has helped about 40% of its participants in being promoted or changing jobs. The effectiveness of IFDC's training in improving job performance was considered to be very good by the participants.

"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."

the late
Dr. John A. Hannah
Chairman Emeritus
IFDC Board of
Directors

Regional Distribution of 1990 Training Participants

Region	Number of Participants
Africa	73 (32%)
Asia	99 (44%)
Europe	11 (5%)
North and Central America	30 (13%)
South America	12 (5%)
Total	225

Ellard Malindi, a participant in the IFDC/Purdue University Training Program on Fertilizer Sector Development in Tropical and Subtropical Countries, considers "the marriage of the agronomic potential of a crop variety with the economics of fertilizer application" to be the most important factor in agricultural development.

Training Events by Region

Africa

Development of Fertilizer Extension Support Materials. January 23-26. Zaria, Nigeria. 24 participants representing 13 of the State Agricultural Development Projects, representatives from the Institute of Agricultural Research, and the Nigerian National Agricultural Extension and Research Liaison Services.

Fertilizer Marketing Training Program. May 14-25. Reduit, Mauritius. 22 fertilizer marketers from 10 countries.

Development of Effective Fertilizer Recommendations. October 16- November 2. Lomé, Togo. 16 professionals from 10 countries, involved in soil fertility, technical assistance, agricultural economics, and production economics.

"People are the common denominator of progress. So . . . no improvement is possible with unimproved people, and advance is certain when people are liberated and educated."

John Kenneth Galbraith

Asia

ICARDA/IFDC Training Course on Development of Effective Fertilizer Recommendations for the Mediterranean Region. February 18-March 9. Aleppo, Syria. 8 participants in charge of making fertilizer recommendations in 5 countries of the region of the International Center for Agricultural Research in the Dry Areas (ICARDA).

Fertilizer Distribution and Handling Training Program. November 12-30. India, Singapore, and Indonesia. 19 senior-level officials (from 10 countries) in governmental or industrial organizations with responsibilities for planning, organizing, operating, and developing systems for physical distribution of fertilizers.

Fertilizer Marketing Training Program. December 3-14. Indonesia. 23 managers (from 10 countries) of fertilizer marketing functions

Headquarters and Other U.S. Locations

Advances in Fertilizer and Irrigation Technology in the United States. June 11-29. Alabama, California, Kansas, Illinois, Missouri, and Louisiana. 21 managers of fertilizer and input organizations and senior government officials (from 13 countries), responsible for establishing strategies for fertilizer, irrigation, and related sectors in developing countries.

IFDC/Auburn University Soil Testing, Classification, and Fertilizer Management Training Program. July 10-12. Headquarters. 4 agronomists and soil scientists from 4 countries, engaged in soil testing and soil fertility research and management.

IFDC/Purdue University Training Program on Fertilizer Sector Development in Tropical and Subtropical Countries. July 23- August 3. Headquarters. 11 graduate students from 9 countries, possessing B.S. or equivalent degrees in agronomy, business, chemistry, economics, engineering, marketing, management, or soil science.

Fertilizer Marketing Management Training Program. August 6- September 14. Headquarters and other U.S. locations. 16 fertilizer marketing managers (from 10 countries) with three or more years of experience in managing fertilizer marketing organizations.

Computer Simulation of Crop Growth and Management Responses. August 13-24. University of Florida, Gainesville, Florida. 19 professionals from 10 countries, currently engaged in crop production-related research or planning.

Urea-Based NPK Plant Design and Operating Alternatives. September 17-28. Headquarters. 49 delegates from 19 countries, representing engineering firms and operating companies having an interest in NPK fertilizers and desiring a better understanding of the use of urea in these types of fertilizers.

Technical Management of Fertilizer Production Units. October 9- 26. Headquarters and other U.S. locations. 17 fertilizer plant managers, production superintendents, scheduling and procurement engineers, process/project engineers, and first- line plant supervisors from 6 countries.

Participants' Insights on IFDC Training

Ellard Malindi
Ministry of Agriculture
Malawi

Ellard Malindi of the Ministry of Agriculture in Malawi knows firsthand the value of training in developing an effective fertilizer sector. As head of his country's National Extension Service, he is responsible for the training and work of 2,400 extension agents throughout Malawi.

Malindi participated in IFDC's Training Program on Fertilizer Sector Development in Tropical and Subtropical Countries, conducted at Headquarters during July 23-August 3, 1990.

"We discussed the development of a fertilizer supply program, the improvement of the use efficiency of fertilizer to increase food production, the proper management of the extension service, the determination of future fertilizer demand, and the classification of soils and their fertility status," Malindi says. "For example, I learned how to determine the fertilizer requirements of our main food crops in Malawi—rice and maize."

For Malindi, the most important factor in agricultural development is "marrying the agronomic potential of a crop variety with the economics of fertilizer application." In future programs of this nature, he hopes that IFDC will devote more time to the economics of fertilizer use so as to answer the question, "How profitable is a particular agronomic practice?"

Taher Mahmood Salama Mehana
El Nasr Company for Chemical Industries
Egypt

Taher Mahmood Salama Mehana of the El Nasr Company for Chemical Industries (SEMADCO) in Egypt has a keen appreciation for the training that he and his colleagues gained at IFDC during the program on "Technical Management of Fertilizer Production Units," during October 9-26, 1990, at IFDC Headquarters.

Specifically, Salama emphasized that "equipped with the new technology and methods of fertilizer production, all of the young managers from developing countries are better able to take on their responsibilities for the development and progress of both their companies and their people."

M. A. Wadud, Controller of Accounts, Bangladesh Agricultural Development Corporation, and Isaac Kirimi, Assistant Director of Agriculture, Kenyan Ministry of Agriculture, participated in the Fertilizer Marketing Management Training Program. They both valued the practical information that they gained from the program, which they can apply in their own countries.

Isaac Kirimi
Assistant Director of Agriculture
Ministry of Agriculture
Nairobi, Kenya

"This program gave me a chance to gain a deeper insight into the marketing component in preparation for the implementation of Kenya's ten-year market development program."

This statement summarized the reaction of Isaac Kirimi, Assistant Director of Agriculture, Ministry of Agriculture, Nairobi, Kenya, to the 1990 Fertilizer Marketing Management Training Program.

This training program provided the participants with many practical applications that can be beneficial in their own fertilizer sectors. For example, Kirimi says, "The discussions on soil testing will be very helpful in my work back home, especially since we are in the process of establishing soil testing units in Kenya."

M. A. Wadud
Controller of Accounts
Bangladesh Agricultural Development Corporation

Another participant in the Marketing Management program, M. A. Wadud, Controller of Accounts, Bangladesh Agricultural Development Corporation, found the training experience to be quite beneficial. In fact, he mentioned that "after observing methods of fertilizer marketing in a developed country, we can apply these to our own situations in our countries."

Wadud emphasized the value of exposure to the experiences and ideas of participants from other countries. "The interaction with other participants can be very beneficial since I plan to apply their experiences to my situation," he says.

Encouraging Fertilizer and Nutrient Management Policies for Agricultural Production

In most developing countries future increases in crop output will depend critically on efficient and environmentally safe fertilizer use for several reasons. First, there is no scope for expanding crop area. Hence, further increases in crop production must result from increased crop yields produced by improved seeds, fertilizer use, water management, and better cultural practices. Second, continuous cultivation of lands without proper replenishment of nutrients has resulted in low soil fertility and degraded soils. Fertility levels of such soils can be restored only by proper management of organic and inorganic nutrients and crop residues. Third, increasing population pressures are leading to deforestation and movement of farmers to marginal lands. Such deforestation is adding to global warming and unpredictable rainfall patterns.

Efficient, equitable, and environmentally safe fertilizer use depends not only on sound agronomic practices and appropriate fertilizer products but also on the existence of a conducive economic and policy environment. Inappropriate policies have resulted in either inefficient fertilizer use and environmental degradation and/or loss in crop production and farm incomes. Non-conducive policy environment in many African countries has kept fertilizer use rather low; in fact, sub-Saharan Africa uses only about 9 kilograms per hectare of fertilizer nutrients as compared with 49 kilograms per hectare for Latin America and 115 kilograms per hectare for Asia. In other countries, excessive farm subsidies have led to overuse of fertilizer products creating environmental hazards. Likewise, poor quality control regulations and environmental standards have created environmental pollution in several locations where fertilizers are produced. Hence, IFDC plans to devote resources for collaborating with countries in evaluating, designing, and promoting better fertilizer policies in the 1990s.

"Efficient, equitable, and environmentally safe fertilizer use depends not only on sound agronomic practices and appropriate fertilizer products but also on the existence of a conducive policy environment. Hence, if the right policies are not in place, the policy environment is not conducive for optimum and socially desirable fertilizer use. For instance, if the prevailing crop and fertilizer prices do not provide incentives for farmers to adopt the right type of fertilizer products and practices, it may result in both decreased food production and environmental degradation. As fertilizer use helps in accelerating food production by raising crop yields on good quality arable lands, it can prevent misuse of marginal lands and the associated soil degradation."

Dr. Balu L. Bumb
IFDC Policy Economist

IFDC's fertilizer policy work focuses on: (1) analysis, research, and assessment; (2) design and implementation; and (3) institutional capacity building. Such work is done in three phases. In Phase I IFDC assesses the conduciveness of the existing policy environment and identifies those components or policies that

Ecologically disadvantaged areas and land-poor rural communities have not benefited from advances in technology and will not until their governments institute policies that give farmers the necessary incentives.

retard growth. In Phase II IFDC is involved in designing and implementing the changes to policy program so that nonconducive policies can be phased out. This phase is usually a long-term exercise. For example, to institute viable marketing policies and develop a competitive fertilizer marketing system in Bangladesh, IFDC has been working with the Government of Bangladesh and USAID/ Dhaka since 1979. In Phase III IFDC is involved in developing institutional capacity for policy research and analysis and includes the development of marketing systems and design and implementation of country-level databases or data management systems supporting policy analysis, implementation, and evaluation. Usually Phase II and Phase III overlap because the IFDC team works with national counterparts and trains them in policy research and analysis.

Although policy-related constraints vary from one country to the other, most of the policies impinging on the fertilizer-sector operations can be grouped into four primary categories, which include macroeconomic, pricing and subsidy, organizational, and environmental policies. In addition to these policies, a conducive policy environment also includes viable and sustainable measures in the areas of fiscal and antitrust policies, quality control, credit, research and extension, and information in developing policy systems for supporting policy decisions and information dissemination.

Macroeconomic Policies

Inadequate and untimely allocation of foreign exchange and rapid depreciation of national currencies (exchange rate) are major macroeconomic policies that affect various operations in the fertilizer sector. Fertilizer use, production, and imports can be seriously affected by these policies. Because of foreign exchange shortages and debt crises, many countries cannot sustain their commitment to fertilizer imports and thereby fertilizer use. Rapid depreciation of currencies like that in many African countries has resulted in manyfold increases in fertilizer prices and decreases in fertilizer use. For example, in Ghana fertilizer prices increased from ¢600 per product ton in 1982 to ¢84,000 per product ton in 1990 because of depreciation in the exchange rate from ¢2.8=US $1 in 1983 to ¢350=US $1 in 1990. Consequently, fertilizer use decreased from about 30,000 nutrient tons to 10,000 tons during that period. Proper sequencing and phasing of such policy shocks

are essential to sustain growth in fertilizer use and crop production and thereby in rural incomes and employment.

Pricing and Subsidy Policy

The main objective of a pricing policy is to provide incentives for efficient input use. In this arena, both crop and fertilizer prices are important. Another objective of the pricing policy is to provide a stable environment so that fluctuations in prices and profitability of fertilizer use are minimized. High price fluctuations may produce cyclical investment and production behavior leading to excessive surpluses or deficits in crop markets and thereby reduced incentives for adoption of new technologies including fertilizer use. In many African and Latin American countries, the lack of a stable and remunerative pricing environment contributed to discourage fertilizer use in the 1980s.

Another issue in this area is that of fertilizer subsidy. The challenge here is to determine the optimum level of fertilizer subsidies so that food security may not be impaired. Because fertilizer and farm subsidies ultimately create fiscal burdens and become unsustainable, a critical evaluation of this policy is necessary. However, it must be stressed that the pricing and subsidy policy must be evaluated in a dynamic context of the changing social and economic goals.

Not only is an evaluation of the subsidy policy important, but also proper sequencing and phasing are required to introduce changes in the policy environment. Ad hoc policy changes may become counterproductive and unsustainable and therefore may require policy reversals. On the other hand, well-managed and properly phased policy reforms are not only sustainable but also contribute to increased crop production and farm incomes through increased fertilizer use. IFDC-managed and implemented policy reforms in Bangladesh provide an example. Unlike Senegal and Venezuela where the removal of fertilizer subsidies led to decreased fertilizer use, in Bangladesh the removal of fertilizer subsidies led to decreased fertilizer prices and increased fertilizer use. This result was achieved by synchronizing the subsidy removal programs with the development of a competitive market system, which promoted increased efficiency and decreased costs in marketing and distribution of fertilizer products.

"In many developing countries where the generation and application of new knowledge and technologies are badly needed to improve income and employment opportunities and to reduce hunger and malnutrition, both researchers and policymakers should work collaboratively because research without practical use is barren and policies without sound technical foundations are naive."

Dr. Balu L. Bumb
IFDC Policy Economist

Organizational Policy

Many developing-country governments have created inefficient and costly monopolies for fertilizer import, production, and distribution. The costs of these inefficiencies are borne by taxpayers. In the initial stage of development when fertilizer products are new and the fertilizer market is small, the direct involvement of governmental agencies may be desirable. However, when the market is fully developed, the continued presence of the government in marketing and distribution of fertilizers may become counterproductive. For example, in many African countries, farmers must travel an average of 18 miles to buy a bag of fertilizer. Furthermore, because the governmental depots are open only on a limited number of days and hours in a week or month, many farmers must make several trips to buy even a small quantity of fertilizer. Such marketing arrangements discourage fertilizer use and prevent potential increases in crop production and farm incomes.

A competitive marketing system eliminates these inefficiencies and provides fertilizer at a lower cost and on time as has happened in Bangladesh, with IFDC assistance. A recent article in the *Bangladesh Times* stated:

"Fertilizer Sales Increase by 20 Percent (over 1989 level)... Farm-level prices of fertilizer fell by at least 20 percent in 1989/90 over the previous year due to increased role of private sector in distribution and marketing."

Likewise, efficient organizational arrangements are also needed for fertilizer imports and production. However, because of economies of scale and foreign exchange requirements, the type and size of viable organizations for these activities may differ from those for marketing and distribution. A proper analysis of the country's needs, resources, and the level of development is required to identify viable and sustainable organizations for various domains of the fertilizer sectors in the developing countries.

"Undoubtedly, household food security is the salient goal of small-scale farmers in developing countries. When asked about goals, farmers usually respond with: 'To eat well.' The sale of food crop production usually only occurs after household food needs have been satisfied or when cash is needed for a specific household purpose. Potential returns from innovative agricultural practices also mean risk associated with change; the maintenance of adequate production for immediate needs is of paramount importance to farmers. Fertilizer use can make a substantial contribution in this respect."

Dr. Thomas P. Thompson
IFDC Rural Sociologist

Environmental Policy

The lack of proper environmental policy has led directly to soil degradation, and indirectly is the cause of deforestation and desertification in many developing countries and pollution of land, air, and water in the developed countries. Unless proper measures are developed and appropriate policies are introduced, the latter environmental problems may also be inflicted upon many developing countries. Thus, the identification and promotion of environmentally safe fertilizer practices and products are essential to achieve multiple objectives of food security, a clean environment, and a sustainable resource base. Through its research and development programs, IFDC plans to assist many developing countries in achieving these objectives during the 1990s.

IFDC Current Activities

IFDC is currently involved in assessing and designing conducive policy environments for fertilizer-sector development in Ghana, Mali, and Malawi. In addition to working with the host-country researchers and policymakers, work has been conducted in these countries to develop relevant information concerning fertilizer use, marketing, imports, structural adjustment programs, food security, and agricultural growth. These activities are being supported by institutional strengthening activities consisting of the development of computerized fertilizer policy databases and information systems and the organization of a National Fertilizer Policy Unit with the purpose of providing information and policy alternatives to relevant government ministries and departments. A prototype database and information system created for Ghana includes modules on fertilizer data (offtake, production, and prices); crop data; agroecological information; agricultural research indicators; and land, agricultural, and economic development indicators. IFDC is also working with the field offices of USAID in these

countries. These efforts are being carried out under a collaborative IFDC/International Food Policy Research Institute (IFPRI) project funded by USAID.

A young Nigerien girl carries firewood while her mother carries a stack of millet. IFDC encourages developing countries to implement policies that lead to environmentally sound sustainable agriculture.

"The desire to understand the world and the desire to reform it are the two great engines of progress."

Bertrand Russell

IFDC 1990 Donors

American Phosphate Foundation (APF)
Der Bundesminister für Wirtschaftliche Zusammenarbeit (BMZ)
Directoraat Generaal voor Internationale Samenwerking (DGIS)
Finnish Department for International Cooperation (FINNIDA)
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)

The Irazu volcano in Costa Rica, with coffee plantations in the foreground.

International Fertilizer Development Center
1991

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	3,460,000 annually	1975 - continuing
	World Bank	200,000 annually	1989 - continuing
IFDC-Africa Development Grants:			
An assistance grant for establishment and maintenance of the IFDC Africa Division.	BMZ UNDP W.K. Kellogg DGIS	2,800,000	1987-1990 1987-1991
Restricted			
Research and Human Resource Development:			
Supplementary Assistance Grant to enable IFDC to undertake urgent preparatory work for its Africa Division and to continue, expand, and intensify the research, training and technology transfer program for the fertilizer sector in the tropics and subtropics, in order to increase and sustain food production.	UNDP	2,600,000	1987-1990
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	1990-1995
Africa			
A Plan of Action for Burundi			
The collection,testing, and production of fertilizers for soil improvement through the beneficiation of Matongo phosphate ore and conversion to single superphosphate and partially acidulated phosphate rock for shipment to Burundi for agronomic tests.	Govt. of Burundi	355,000	1987-1990
Collection and Dissemination of Fertilizer Information			
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	1,600,000	1988-1991
East and Southeast Africa Network			
To conduct field evaluations of phosphate products often made from indigenous resources of the region. To derive agronomic and economic benefit from these locally available resources and supplement phosphate fertilizers primarily supplied from imports.	World Bank	300,000 annually	1986 - continuing
Fertilizer Distribution Study/Algeria			
The development of a comprehensive fertilizer supply strategy which involves examining the current status of and making recommendations for improving the essential and interdependent fertilizer use, supply, and marketing components of the fertilizer sector.	World Bank	288,000	1990
Fertilizer Investment for Soil Fertility Restoration			
To identify the constraints to fertilizer adoption in various agro-ecological 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	1987-1992

Project/Purpose	Funding Source	(U. S. Dollars)	Duration
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	1987-1992
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	1990-1994
Geology Volta Basin Study Evaluation of undeveloped phosphate deposits in West Africa.	BMZ	584,000	1988-1990
Marketing Study In Tanzania To determine the potential markets for the sale of phosphate fertilizers by the Minjingu Phosphate Company.	FINNIDA	33,000	1990
On-Farm Evaluation and Adoption To demonstrate that farmer participation is an essential component of the technology transfer process.	IDRC	860,000	1989-1992
Studies and Experimental Assessment on NPK (Plus) Conduct a feasibility 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	1989-1993
Technical Assistance to Zambia A study of the fertilizer procurement system in Zambia.	Nathan Associates	32,000	1990
Training of Rockefeller Visiting Scientist Training of Mr. Elias T. Ayuk in on-farm fertilizer evaluation and adoption in West Africa; while located at the IFDC-Africa Division.	Rockefeller	80,000	1990-1991
West African Fertilizer Management and Evaluation Network Evaluation of fertilizer sources and management techniques in West Africa.	IDRC	688,000	1985-1990
Asia			
Fertilizer Distribution and Marketing Consultancy Services to the Government of Bangladesh To assist the Bangladesh Ministry of Agriculture to improve fertilizer marketing by incorporating private-sector concepts and resources.	Govt. of Bangladesh	9,900,000	1987-1991
Research and Development for Texasgulf Provided greenhouse evaluation of partially acidulated phosphate rock (PAPR).	Texasgulf	32,600	1990
Studied the potential to use reactive phosphate rock.	Texasgulf	300,000	1987-1990
Latin America			
Agronomic Evaluation of Phosphate & Magnesium Availability of Fosmag on High Phosphorus-Fixing Soils To provide additional information on crop response to Fosmag so that sound agronomic understanding of the product can be developed.	MANAH,S.A.	24,100	1990

Project/Purpose	Funding Source	(U. S. Dollars)	Duration
Evaluation of Plant Operations in Costa Rica Evaluation of plant operations to increase efficiency and profitability.	FINTRA	153,000	1990
Evaluation of Phosphate Raw Materials from Chile Characterization and beneficiation of phosphate.	SQM	18,000	1990
Lab-Scale Production of Phosphoric Acid and DAP from Venezuelan ores Beneficiation and acidulation of Venezuelan phosphate ores.	INTEVEP	140,000	1990
Material Evaluation and Production Laboratory/Feasibility Study of Urea-Urease Inhibitor Compatibility.	Enimont	72,000	1990
Pilot Plant Granulation of NPK fertilizers To increase the production capacity of a granulation plant for compound NPK fertilizer and eliminate the importation of raw materials.	MONOMEROS	76,000	1990

Financial Report

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Suite 1400
Atlanta, GA 30339

Telephone 404 933 9191

Price Waterhouse

Report of Independent Accountants

March 15, 1991

To the Board of Directors of
International Fertilizer Development Center

In our opinion, the accompanying balance sheets and the related statements of revenue and 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, 1990 and 1989, 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

CURRENT FUND

	December 31, 1990	December 31, 1989
Cash and cash equivalents	$2,500,773	$2,718,855
Amounts receivable from donors (Notes 1 and 2)	5,338,454	5,504,012
Other accounts receivable	1,304,284	925,421
Advances to employees	99,769	132,360
Supplies inventory (Note 1)	177,024	150,281
Prepaid expenses	368,783	383,670
	$9,789,087	$9,814,599

LIABILITIES AND FUND BALANCES

CURRENT FUND

	December 31, 1990	December 31, 1989
Accounts payable	$ 293,450	$ 319,839
Accrued annual and sick leave	1,862,412	1,738,269
Deferred revenue (Notes 1 and 2)	6,269,648	6,536,028
Total liabilities and deferred revenue	8,425,510	8,594,136
Fund balance	1,363,577	1,220,463
	$9,789,087	$9,814,599

NONCURRENT FUND

	December 31, 1990	December 31, 1989
Amounts receivable from donors (Noes 1 and 2) - restricted	$6,615,625	$1,999,320
Deferred revenue (Notes 1 and 2) - restricted	$6,615,625	$1,999,320

BUILDINGS AND EQUIPMENT FUND

(Note 1)

	December 31, 1990	December 31, 1989
Buildings	$5,969,171	$5,904,558
Equipment	5,340,099	5,378,841
Less - Accumulated depreciation	(6,808,860)	(6,607,655)
	$4,500,410	$4,675,744

	December 31, 1990	December 31, 1989
Contract retainage	$ 421	$ 421
Lease obligation (Note 4)	38,998	56,564
Fund balance	4,460,991	4,618,759
	$4,500,410	$4,675,744

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

INTERNATIONAL FERTILIZER DEVELOPMENT CENTER

STATEMENTS OF REVENUE AND EXPENSES AND CHANGES IN FUND BALANCES

FOR THE YEARS ENDED DECEMBER 31, 1990 AND 1989

	Current Fund		Buildings and Equipment Fund		Total All Funds	
	1990	1989	1990	1989	1990	1989
Revenue:						
Grants (Note 2)	$ 8,702,250	$ 8,054,003	$	$	$ 8,702,250	$ 8,054,003
Recovered project costs	4,383,582	3,811,690			4,383,582	3,811,690
Other	157,514	175,838			157,514	175,838
Total revenue	13,243,346	12,041,531			13,243,346	12,041,531
Expenses:						
Field programs	3,150,681	3,147,451	127,739	127,000	3,278,420	3,274,511
Research	3,595,782	3,445,819	208,580	226,216	3,804,362	3,672,035
Outreach	3,606,475	2,864,494	52,120	50,104	3,658,595	2,914,598
General and administrative	2,429,952	2,140,078	86,671	82,982	2,516,623	2,223,060
Total expenses	12,782,890	11,597,842	475,110	486,362	13,258,000	12,084,204
Excess (deficiency) of revenue over expense	460,456	443,689	(475,110)	(486,362)	($ 14,654)	($ 42,673)
Other changes in fund balances:						
Transfers from current fund for equipment acquisitions and capital lease payments	(317,342)	(283,807)	317,342	283,807		
Fund balances, beginning of period	1,220,463	1,060,581	4,618,759	4,821,314		
Fund balances, end of period	$ 1,363,577	$ 1,220,463	$ 4,460,991	$ 4,618,759		

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, 1990 AND 1989

	Field Programs		Research		Outreach		Administrative		Total Expenses	
	1990	1989	1990	1989	1990	1989	1990	1989	1990	1989
Personnel compensation (Note 3)	$1,172,551	$1,118,106	$1,908,935	$1,743,871	$1,571,740	$1,252,071	$1,358,999	$1,124,525	$ 6,012,225	$ 5,238,573
Personnel benefits (Note 3)	451,498	464,058	498,580	450,147	391,158	357,810	311,901	279,479	1,653,137	1,551,494
Travel and transportation	380,760	454,127	253,521	261,874	430,498	399,401	174,855	179,011	1,239,634	1,294,413
Occupancy	45,373	32,269	257,202	242,558	133,100	121,351	128,601	121,279	564,276	517,457
Telephone and telegraph	84,326	68,104	26,491	33,449	39,945	32,030	21,474	22,660	172,236	156,243
Rental of equipment	49,367	42,697	23		98,490	1,217	1,112	1,598	148,992	45,512
Contractual research and development	186,356	118,983	181,915	198,903	18,500		16,392	70,545	403,163	388,431
Other contractual services	367,197	251,980	163,654	230,375	492,862	418,734	170,571	48,402	1,194,284	949,491
Institute of International Education fee (Note 3)							135,192	135,973	135,192	135,973
Materials and supplies	390,309	578,752	258,075	236,422	375,158	243,827	87,882	130,287	1,111,424	1,189,288
Postage	10,906	9,563	15,407	20,421	24,494	24,153	7,086	12,419	57,893	66,556
Insurance	12,038	8,812	31,979	27,799	30,530	13,900	15,887	13,900	90,434	64,411
Miscellaneous	21,314		1,441		804		17,706		41,265	
Total expenses before depreciation	3,171,995	3,147,451	3,597,223	3,445,819	3,607,279	2,864,494	2,447,658	2,140,078	12,824,155	11,597,842
Depreciation of buildings and equipment	106,425	127,060	207,139	226,215	51,316	50,105	68,965	82,982	433,845	486,362
Total expenses	$3,278,420	$3,274,511	$3,804,362	$3,672,034	$3,658,595	$2,914,599	$2,516,623	$2,223,060	$13,258,000	$12,084,204

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, 1990 AND 1989

	1990	1989
Cash flows from operating activities:		
Deficiency of revenue over expenses	($ 14,654)	($ 42,673)
Adjustments to reconcile deficiency of revenue over expenses to net cash provided by operating activities:		
Depreciation	433,845	486,362
Loss on disposal or donation of equipment	41,265	2,310
Changes in assets and liabilities:		
(Increase) decrease in receivables from donors	(4,450,747)	634,117
(Increase) decrease in advances to employees	32,591	(33,571)
(Increase) decrease in other accounts receivable	(378,863)	702,136
(Increase) decrease in prepaid expenses	14,887	(135,033)
(Increase) decrease in supplies inventory	(26,743)	(24,018)
Increase (decrease) in accounts payable and accrued expenses	97,754	(279,759)
Increase (decrease) in deferred revenue	4,349,925	(340,114)
Increase (decrease) in contract retainage		206
Net cash provided by operating activities	99,260	969,963
Cash flows from investing activities:		
Capital expenditures	(299,776)	(257,431)
Net cash used in investing activities	(299,776)	(257,431)
Cash flows from financing activities:		
Principal payments under capital lease obligation	(17,566)	(28,892)
Net cash used in financing activities	(17,566)	(28,892)
Net cash flow	(218,082)	683,640
Beginning cash and cash equivalents	2,718,855	2,035,215
Ending cash and cash equivalents	$2,500,773	$2,718,855

INTERNATIONAL FERTILIZER DEVELOPMENT CENTER

NOTES TO FINANCIAL STATEMENTS

NOTE 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.

NOTE 2 - GRANTS:

Grants are summarized as follows:

	Year ended December 31, 1990		1989	
	Restricted	Unrestricted	Restricted	Unrestricted
Grants received				
United States Agency for International Development (AID)	$ 52,904	$3,398,000	$ 1,629,500	$3,460,000
United Nations Development Programme (UNDP)	2,900,000		63,524	
International Development Research Centre (IDRC)	47,243		991,123	
Rockefeller Foundation	60,000			
DirectoraatGeneralaal voor Internationale Samenwerking (Netherlands) (DGIS)	132,297		693,457	
World Bank	5,500,000	770,000		1,070,000
Der Bundesminister fur Wirshaftliche Zusammenarbeit (BMZ)	128,400			
	8,820,844	4,168,000	3,377,604	4,530,000
Amounts deferred during prior year	5,863,973	2,569,125	7,102,020	1,490,000
	14,684,817	6,737,125	10,479,624	6,020,000
Less - amounts deferred to future periods	(9,800,575)	(2,895,789)	(5,863,973)	(2,569,125)
Other adjustments	(23,328)		(12,523)	
Revenue recognized in current period	$ 4,860,914	3,841,336	$ 4,603,128	3,450,875
		4,860,914		4,603,128
Total restricted and unrestricted		$8,702,250		$ 8,054,003

In addition to grant amounts deferred to future years, as indicated above, deferred revenue at December 31, 1990 and 1989 includes $188,909 and $102,250, respectively, of cash collected on reimbursable cost projects for which revenue has not been recognized.

During 1990, IFDC received restricted grants relating 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 have terms of four and five years, respectively. Additional funding to support the Togo Center was obtained by DGIS during 1990 and this grant will expire in June, 1991.

The restricted grants received during 1989 relate almost exclusively to fertilizer research projects in Africa. The AID grant provides additional funds for fertilizer policy research under a grant which expires July 30, 1992. One IDRC grant provides $131,645 for development of efficient fertilizer usage techniques and the second provides $859,478 for promoting fertilizer use by African farmers; the first grant expired March 31,1990 and the second expires April 30, 1992. The DGIS grant provides additional funds to support the Togo Center in monitoring, collecting and disseminating fertilizer information in Africa. The UNDP grant relates to fertilizer research and training, but is not restricted to Africa.

Receivables from donors at December 31, 1990 and 1989 are summarized as follows:

	Year ended December 31, 1990		1989	
	Restricted	Unrestricted	Restricted	Unrestricted
AID	$1,785,112	$1,685,788	$3,050,871	$1,629,125
DGIS	343,255		878,977	
UNDP	2,252,684		940,290	
IDRC	521,699		725,278	
Rockefeller Foundation	120,000		60,000	
World Bank	5,026,750			
BMZ	218,791		218,791	
	10,268,291	1,685,788	5,874,207	1,629,125
Less - Noncurrent portion	6,615,625		1,999,320	
	$3,652,666	1,685,788	$3,874,887	1,629,125
		3,652,666		3,874,887
Total restricted and unrestricted		$5,338,454		$5,504,012

NOTE 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.

NOTE 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, 1990	1989
Office Equipment	$130,672	$130,672
Less: accumulated depreciation	40,818	29,929
	$ 89,854	$100,743

As of December 31, 1990, future minimum lease payments are as follows:

1991	$21,126
1992	21,126
	42,252
Less - Amounts representing interest	3,254
Present value of minimum lease payments	$38,998

1990 IFDC Publications

The following are publications released by IFDC during 1990. A complete list of IFDC publications is available upon request.

Proceedings

Fertilizer Policy in Tropical Africa, Workshop Proceedings. (SP-10) ($30)

Supplying Quality Multinutrient Fertilizer in the Latin American and Caribbean Region Emphasizing Bulk Blending and the Complementary Role of Granulation, Workshop Proceedings. (SP-14) ($40)

Paper Series

Fertilizer Situation and Markets in Malawi. (P-12)*

Production et Approvisionnement en Engrais en Afrique Sub-Saharienne: Constraintes et Options. (P-13)*
(French version of *Fertilizer Production and Supply Constraints and Options in Sub-Saharan Africa*) (1989). (P-10)*

Technical Bulletins

Fertilizer Use Statistics and Crop Yield. (T-37)*

Analyse et Perspectives de Developpement des Engrais dans le Monde, 1960-95, Résumé Analytique. (T-38) ($10)
(French version of *Global Fertilizer Perspective, 1960-95: The Dynamics of Growth and Structural Change)* (1989) (T-35) ($10)

Perspectiva Global de Fertilizantes, 1960-95, Resumen Ejecutivo. (T-39) ($10)
(Spanish version of *Global Fertilizer Perspective, 1960-95: The Dynamics of Growth and Structural Change*) (1989) (T-35) ($10)

A Model for a Fertilizer Information Unit in Developing Countries. (T-40)*

Journal Articles
(Nitrogen)

De Datta, S. K., R. J. Buresh, W. N. Obcemea, and E. G. Castillo. 1990. "Nitrogen-15 Balances and Nitrogen Fertilizer Use Efficiency in Upland Rice," *Fertilizer Research*, 26:179-187. (B-145)**

Rutland, D. W., and J. R. Polo. 1990. "Urea in NPK Fertilizers: How Much Can You Use?" *Phosphorus & Potassium*, 166(March-April):25-32. (B-149)**

Byrnes, B. H. 1990. "Environmental Effects of N Fertilizer Use—An Overview," *Fertilizer Research*, 26:209-215. (B-151)**

Carmona, G., C. B. Christianson, and B. H. Byrnes. 1990. "Temperature and Low Concentration Effect of the Urease Inhibitor N-(n-Butyl)Thiophosphoric Triamide (n-BTPT) on Ammonia Volatilization From Urea," *Soil Biology and Biochemistry*, 22(7):933-937. (B-152)**

Savant, N. K., and S. H. Chien. 1990. "Greenhouse Evaluation of Urea Supergranules (USG) Containing Diammonium Phosphate (DAP) for Transplanted Rice," *International Rice Research Newsletter*, 15(3):23 (B-153)**

Ssali, H. 1990. "Initial and Residual Effects of Nitrogen Fertilizers on Grain Yield of a Maize/Bean Intercrop Grown on a Humic Nitosol and the Fate and Efficiency of the Applied Nitrogen," *Fertilizer Research*, 23:63-72. (B-154)**

Phongpan, Sakorn, and B. H. Byrnes. 1990. "The Effect of the Urease Inhibitor N-(n-butyl) Thiophosphoric Triamide on the Efficiency of Urea Application in a Flooded Rice Field Trial in Thailand," *Fertilizer Research*, 25:145-151. (B-155)**

Byrnes, B. H., C. B. Christianson, L. S. Holt, and E. R. Austin. 1990. "Nitrous Oxide Emissions From the Nitrification of Nitrogen Fertilizers," IN *Soils and the Greenhouse Effect*, pp. 489-495, A. F. Bouwman (Ed.), John Wiley & Sons Ltd. (B-156)**

Samson, M. I., R. J. Buresh, and S. K. De Datta. 1990. "Evolution and Soil Entrapment of Nitrogen Gases Formed by Denitrification in Flooded Soils," *Soil Science and Plant Nutrition*, 36(2):299-307. (B-157)**

Savant, N. K., and P. J. Stangel. 1990. "Deep Placement of Urea Supergranules in Transplanted Rice: Principles and Practices," *Fertilizer Research*, 25(1):1-83. (Special Issue) (B-159) ($35)

De Datta, S. K., R. J. Buresh, and C. P. Mamaril. 1990. "Increasing Nutrient Use Efficiency in Rice With Changing Needs," *Fertilizer Research*, 26:157-167. (B-165)**

Padilla, J. L., R. J. Buresh, S. K. De Datta, and E. U. Bautista. 1990. "Incorporation of Urea in Puddled Rice Soils as Affected by Tillage Implements," *Fertilizer Research*, 26:169-178. (B-166)**

(Phosphate)

Menon, R., S. H. Chien, and L. L. Hammond. 1990. "Development and Evaluation of the Pi Soil Test for Plant-Available Phosphorus," *Communications in Soil Science and Plant Analysis*, 21:1131-1150. (C-91)**

Menon, R. G., S. H. Chien, L. L. Hammond, and B. R. Arora. 1990. "Sorption of Phosphorus by the Iron Oxide-Impregnated Filter Paper (Pi Soil Test) Embedded in Soils," *Plant and Soil*, 126:287-294. (C-93)**

Menon, R. G., and S. H. Chien. 1990. "Phosphorus Availability to Maize From Partially Acidulated Phosphate Rocks and Phosphate Rocks Compacted with Triple Superphosphate," *Plant and Soil*, 127:123-128. (C-94)**

Chien, S. H. 1990. "A Discussion of the Methods for Comparing the Relative Effectiveness of Phosphate Fertilizers Varying in Solubility," *Fertilizer Research*, 24:149-157. (C-95)**

Chien, S. H. 1990. "Agronomic Evaluation of Two Unacidulated and Partially Acidulated Phosphate Rocks Indigenous to Niger," *Soil Science Society of America Journal*, 54(6):1772-1777. (C-96)**

McClellan, G. H., and S. J. Van Kauwenbergh. 1990. "Mineralogy of Sedimentary Apatites," IN *Phosphorite Research and Development*, pp. 23-31, A.J.G. Notholt and I. Jarvis (Eds.), Geological Society Special Publication No. 52. (C-97)**

Van Kauwenbergh, S. J., and G. H. McClellan. 1990. "Comparative Geology and Mineralogy of the Southeastern United States and Togo Phosphorites," IN Phosphorite Research and Development, pp. 139-155, A.J.G. Notholt and I. Jarvis (Eds.), Geological Society Special Publication No. 52. (C-98)**

Leon, L. A. 1990. "LA EFICIENCIA DE LA FERTILIZACION FOSFATADA," *Suelos Ecuatoriales*, Volumen XX, No. 1. (C-99)**

Le Mare, P. H., and L. A. Leon. 1990. "Effects of Residues of Triple Superphosphate on the Quantity-Intensity Relationships of Fresh Phosphate in Some Soils From Brazil and Colombia," *Fertilizer Research*, 24:159-166. (C-100)**

Youngdahl, Leif J. 1990. "Differences in Phosphorus Efficiency in Bean Genotypes," *Journal of Plant Nutrition*, 13(11):1381-1392. (C-101)**

Miscellaneous

Kapusta, E. D. 1990. "International Fertilizer Development Center Training and Technical Assistance Activities: A Review," *Fertilizer Research* 23:43-61. (D-112)**

Henao, J. M. 1990. "METODOS COMPUTARIZADOS PARA EL USO EFICIENTE DE FERTILIZANTES," *Suelos Ecuatoriales*, Volumen XX, No. 1. (D-115)**

Stangel, P. J. 1990. "Future Fertilizer Marketing Opportunities," IN *Proceedings of The Fertilizer Institute's 1990 World Fertilizer Conference*, pp. 130-158, September 16-18, San Francisco, California. (D-117)**

Vlek, P.L.G. 1990. "The Role of Fertilizers in Sustaining Agriculture in Sub-Saharan Africa," *Fertilizer Research*, 26:327-339. (D-118)**

Williams, L. B., and J. J. Schultz. 1990. "A Fertilizer Supply Strategy for Sub-Saharan Africa," IN *Proceedings, Workshop 1989, Feeding the Future: Agricultural Development Strategies for Africa*, pp. 125-153, C. R. Dowswell (Ed.), CASIN/ Sasakawa Africa Association/Global 2000, August 1-3, 1989, Accra, Ghana. (D-119)**

Sulfur

Friesen, D. K. 1990. "Fate and Efficiency of Sulfur Fertilizers Applied to Food Crops in West Africa," *Fertilizer Research*, 29:35-44. (E-13)**

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*US $4.00; non-US $7.50.
**US $3.00; non-US $5.00.

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(as of December 31, 1990)

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§ Amitava H. Roy remained Director of Fertilizer Technology Division until October, when he became Executive Vice President and Chief Operating Officer.

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Kokouvi Tsogbe, Field Technician
Komlan Wogomebu, Jr., Accountant

*Left in 1990.
**Retired in 1990.
***Deceased.
****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.

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(as of December 31, 1990

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Ex Officio Member
Marjorie R. Brashier
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* Deceased.

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(as of July 1991)

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