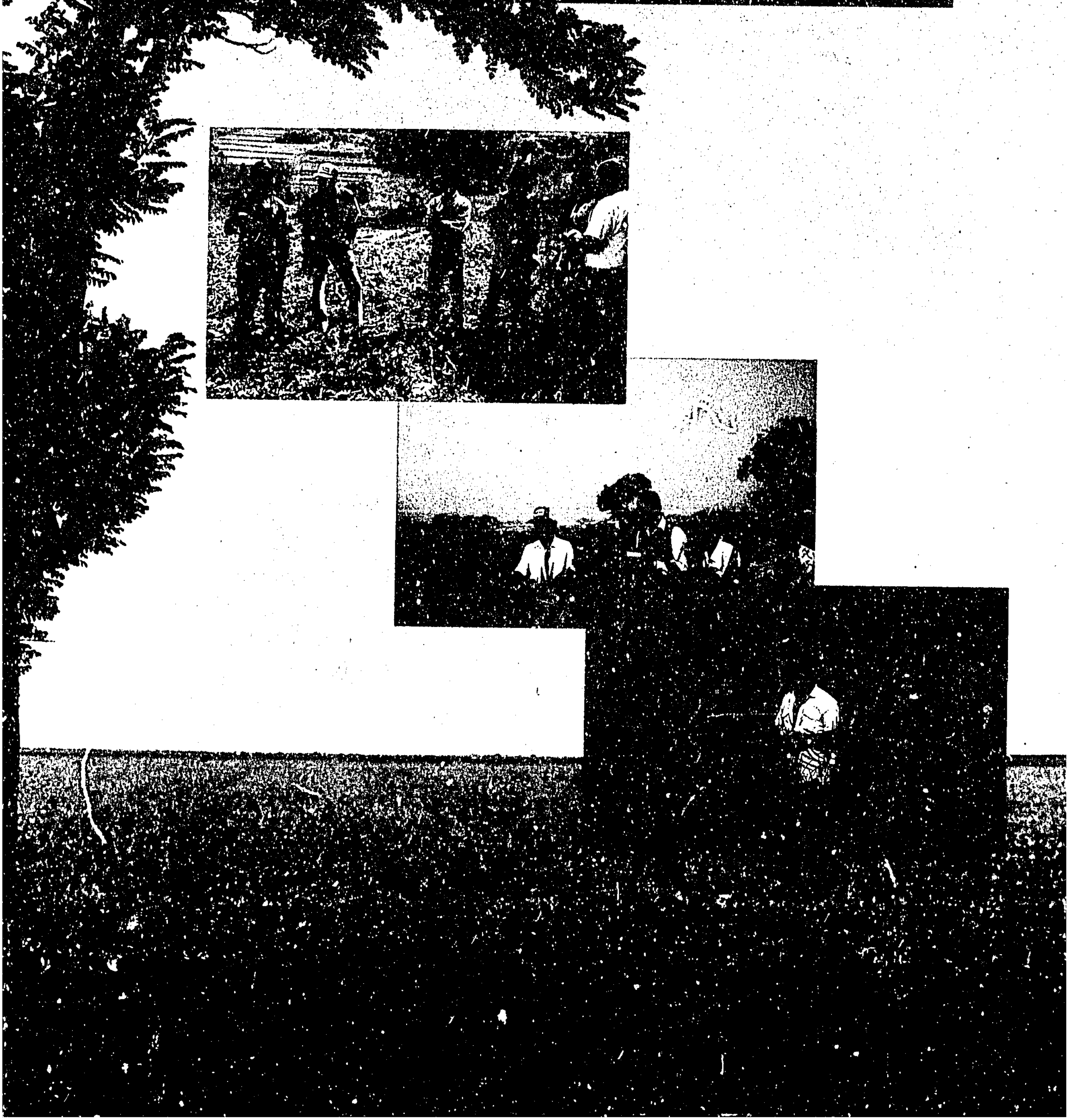
"Networking to Meet Nutrient Challenges"

International Fertilizer Development Center
Annual Report, 1993



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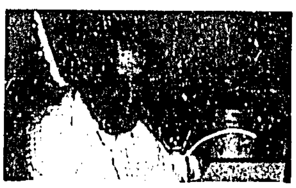

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Message From the President and Chief Executive Officer

The United Nations predicts that by the year 2020 the world's population will most likely have increased by about 2.5 billion to a total of 8 billion people, compared with 5.5 billion today. Over 93% of this growth will occur in the developing countries.

Today more than 700 million people in developing countries do not have access to sufficient food to lead healthy, productive lives. If current trends in population growth and food production continue, by the year 2020, the World Bank estimates that Africa alone will have an annual food shortage of 250 million tonnes.

What is the answer to this dilemma? In the world forum, it has long been known and discussed that agricultural intensification—production of more food on land already under cultivation—is the key to effectively addressing all three challenges simultaneously. Poverty, combined with population pressures, often forces people to cultivate land to its limit and beyond. Indeed, much of the degradation of marginal lands, including deforestation, overgrazing of fragile rangelands, and cultivation of steep slopes, arises from lack of sufficient agricultural intensification on suitable land already under cultivation. Agricultural intensification addresses the root causes of poverty and helps to slow poverty-led environmental degradation. Access to appropriate inputs (especially fertilizers) and better technology are crucial to support agricultural intensification and environmentally sustainable farming practices. The most serious environmental problem in developing countries is not inappropriate technological change in agriculture but the many millions of people who live in absolute poverty and who must exploit natural resources to an excessive degree just to survive.

For the past two decades IFDC has been concentrating on long-term solutions to food production problems and environmental protection. The Center gets to the heart of the problem—low soil fertility and resulting low yields of food crops. We conduct strategic and applied research that seeks to enhance plant nutrient efficiency. The impact of our work is being realized in numerous places; for example, in India IFDC is working with small-scale farmers by providing them with environmentally sound technology that can double their traditional rice yields through a combination of better management and the right types of fertilizers. This technology has the potential of helping resource-poor farmers increase their food production and incomes, while conserving the natural resource base.

IFDC recognizes that in addition to nutrients the management of soil and water is critical to sustainable food production. In this regard IFDC is a member of the consortium of international agricultural research institutes involved in soil, water, and nutrient management research.

In West Africa, IFDC recently completed a 5-year Soil Fertility Restoration Project that involved the participation of 800 men and women farmers in an integrated broad-based approach to rural development. During this project 138 national research and extension staff benefited from 24 group and 11 individual training programs. A fertilizer procurement revolving fund to ensure a timely and steady supply of this input was successfully established in each participating country. Food production and farmer incomes among the fertilizer users in the project doubled while those of nonusers remained the same.

The Center is playing a pivotal role as it provides assistance to the decisionmakers in countries that are involved in the transition from centrally planned economies to free market economies...

As a participant in the Alternatives to Slash and Burn Initiative, IFDC cooperates with national and international organizations of Africa, Asia, and Latin America to develop viable alternatives to the destructive practice of slash and burn agriculture, which is prevalent in the forest margins of many areas of the tropics and subtropics. With seven other international agricultural research centers, IFDC is cooperating on a Desert Margins Initiative, which focuses on arresting land degradation by promoting improved and innovative technologies that integrate effective nutrient management strategies with improved soil and water conservation techniques that are ecologically sound, economically viable, and socially acceptable to farmers in the dryland areas of sub-Saharan Africa.

At the same time, IFDC recognizes that we are living during a dynamic era with dramatic changes occurring throughout the world involving market reform, removal of trade barriers, and emerging democracies. The Center is playing a pivotal role as it provides assistance to the decisionmakers in countries that are involved in the transition from centrally planned economies to free market economies and developing countries that are transferring ownership and management of state-owned enterprises to the private sector. This assistance includes the development and implementation of more effective agricultural policies and the establishment of free market systems for fertilizers and other agricultural inputs. It usually encompasses the creation of a trained cadre of private entrepreneurs who are knowledgeable of the effective and efficient use of agricultural inputs and the development and implementation of information management systems to support agricultural production and market strategies.

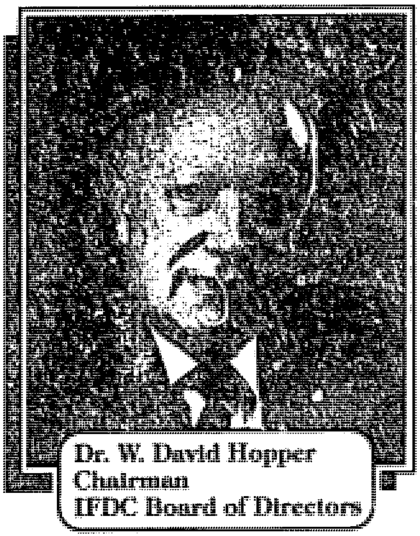
In Bangladesh IFDC has nurtured the development of a free and competitive market system for fertilizers. As a result, fertilizer use has increased by over 100% since the project began in 1979, and the country has virtually achieved self-sufficiency in rice production. The removal of fertilizer subsidies and the impact of privatization resulted in an estimated combined saving of US $43 million during 1992/93 for Bangladesh. Total employment generation due to fertilizer sector privatization is estimated at 170,000, which is generating US $34 million per year in wages.

In Albania IFDC is helping the Albanian people to improve the quality of their lives since we introduced the first successful privatization project in that country. This project, which introduced the free market system in Albania, is increasing agricultural productivity and sustaining the free market economy. IFDC has created a strong, active network of entrepreneurs and trained them in marketing, credit, and financial planning. During 1993 IFDC assisted Albanian officials in laying the groundwork for the establishment of a national agricultural statistical system that will provide the policymakers with access to the information they need to make more informed decisions regarding the future of Albanian agriculture.

We at IFDC look forward to the future with hope and aspiration. We believe that collaboration with our many partners in the national agricultural research systems, nongovernmental organizations, and other international agricultural research centers will result in solutions to the food security challenges that our clients in the developing countries and the newly emerging democracies of Eastern and Central Europe are trying to solve.

Amit H. Roy
President and
Chief Executive Officer

Hopper and the India Connection



Dr. W. David Hopper
Chairman
IFDC Board of Directors

Having had a long and rewarding association with Indian agriculture, Dr. W. David Hopper, Chairman of IFDC's Board of Directors, has observed the ebbs and flows of agricultural development in that country. Returning to India some 40 years after his first stint there, in 1993 he delivered the keynote address at the annual seminar held under the auspices of the Fertiliser Association of India.

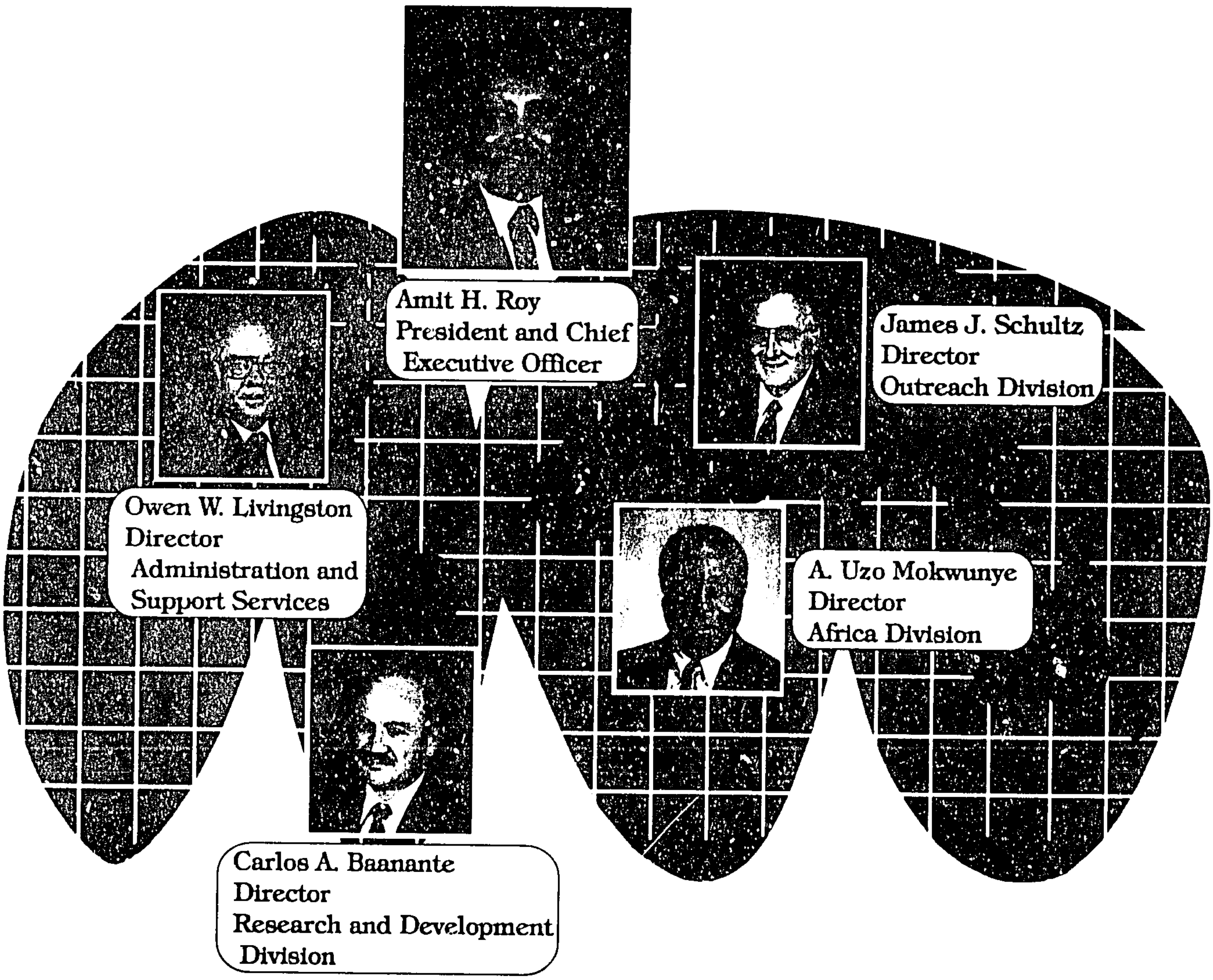
In his presentation entitled "Indian Agriculture and Fertiliser: An Outsider's Observations," Hopper reminded his audience that 26 years ago Indian farmers had just completed the first commercial planting of the new dwarf varieties of wheat. Those plantings were nurtured by the heaviest application of fertilizer in Indian history. The outcome of these plantings in the spring of 1968 was 50% above the previous 12 million-ton record harvest of 1965. The harvest of 1968 marked a transition from an agrarian India to an Indian agriculture founded on modern science-derived technologies.

The main thrust of Hopper's speech was concerned with the implications of that transition in Indian agriculture. Transporting his audience back in time, Hopper recounted that India's agricultural development strategy before the very difficult drought years of the mid-1960s was based on twin thrusts—a slow increase in acreage and improved cultural practices to enhance yields. The result of this strategy was an almost stagnant growth in food grain output. Finally, after becoming exasperated by the stubborn 2-year drought of the mid-1960s, the Minister of Food and Agriculture placed the nation firmly on the path of modern agricultural development in 1966 by importing 18,000 tons of dwarf wheat seed from Mexico. The productivity of the new seeds was ensured when the World Bank and the bilateral aid donors of the Indian Consortium agreed to provide fertilizer imports for the nation's wheat farmers. The result is history—Indian grain production broke all previous records.

As the arable land of the nation diminishes under increasing population pressures, future growth of the nation's food supply can come only from a continued growth in yields. In other words, the factors of production that will promote the increase of grain yields must become the major ingredient of agricultural development policy, indeed, for any national policy for food security. Obviously, fertilizer is one of the most significant factors of production. Fertilizer policy, therefore, must be at the center of any policy for the nation's food economy.

Looking at the present situation, Hopper pointed out that of the 180 plus million tonnes of food grain produced in India today, fertilizer probably accounts for 75 to 90 million tonnes of the total. Almost one-half of the nation's domestic food production can be attributed to the application of plant nutrients.

IFDC Management Team



Note: IFDC Management Team also includes the Director of the Asia Division — position vacant.

Guest Essay by Dr. Norman Borlaug

Fertilizer: To Nourish Infertile Soil That Feeds a Fertile Population That Crowds a Fragile World

Introduction

1994 marks my 50th year of continuous involvement in food production programs in developing nations. During this period, I have seen the disastrous hunger and misery of many millions of poor small-scale farmers in scores of countries who are trying to eke out a living on impoverished soils. My personal involvement in the development of improved agronomy and especially the proper use of fertilizer to restore soil fertility to "worn out" soils dates back to my initial work in Mexico. It became our standard practice that whenever a new wheat variety was being tested or demonstrated on farms or in seed production fields, the best possible package of agronomic practices was employed, including the application of near-optimum levels of the right kind of fertilizer, the best date and rate of seeding, timely weed control, and optimum use of moisture be it from rainfall or irrigation.

Dr. Norman E. Borlaug
Recipient of the Nobel Peace Prize, 1970

The advent of cheap and plentiful chemical fertilizers has been one of the great agricultural achievements of this century.

Over the past three decades, the use of improved varieties of maize, wheat, rice, and other food crops; a tenfold global increase in chemical fertilizer use; more effective control of weeds, diseases, and insects; and a greater reliance on irrigation and/or improved techniques for conserving moisture have allowed world food production to increase more rapidly than global population.

The Green Revolution and Fertilizer's Role

The breakthrough in wheat and rice production in Asia in the mid-1960s, which came to be known as the Green Revolution, started the process of using agricultural science to develop modern techniques for the developing countries. It began in Mexico with the "quiet" wheat revolution in the late 1950s. During the 1960s and 1970s, India, Pakistan, and the Philippines received world attention for their agricultural progress. Since 1980

China has been the greatest success story. Home to one-fifth of the world's people, China today is the world's largest food producer.

The advent of cheap and plentiful chemical fertilizers has been one of the great agricultural achievements of this century. During the past two decades, chemical fertilizers have permitted the densely populated nations of Asia to better feed their burgeoning populations and lower the real cost of food for both the rural and urban poor. Even in China, which makes the best use of recycled organic matter, animal manure, and night soil in the world, huge investments have been made in chemical fertilizer facilities during the past 20 years and virtually all Chinese farmers now use chemical fertilizers. Chemical fertilizer production has increased from 6,000 nutrient tonnes in 1949 to some 24 million tonnes in 1991. In 1992 China was the world's largest producer, importer, and consumer of nitrogen fertilizers and ranked first and second, respectively, in the consumption and production of phosphate fertilizers. China's investments in fertilizer production capacity have paid off handsomely. One of the driving factors in the spectacular Chinese progress in increasing yields and production, especially, has been the 13 large, modern 1,000-tonne-per-day ammonia plants (plus phosphate production) that came on stream in the late 1970s and early 1980s. The other factor has been government policies that liberalized crop production and grain marketing systems, essentially abandoning the commune system. By 1990 China had surpassed the United States as the world's largest cereal producer.

The Green Revolution, however, has not progressed at the same rate everywhere, nor has it reached all crops or all farming areas. Crop yields in many less-developed countries, especially in rainfed tropical and semitropical environments, remain stagnant and abysmally low. During the 1980s per capita food production increased the most in the East and South Asian regions; it is not coincidental that fertilizer consumption in these regions has increased nearly fivefold over the last 20 years, according to World Bank data. In contrast, sub-Saharan Africa had the lowest fertilizer consumption rate — 20% that of Latin America and 5% that of East Asia. Again, not coincidentally, sub-Saharan Africa also recorded the worst performance in food production, with the per capita food production index actually declining.

Looking at the present cereal yield levels of India and the former U.S.S.R., and considering available technology, it should be possible for both to increase grain yields and production greatly over the next decade, providing they maintain political stability, reign in the stifling bureaucracy that destroys entrepreneurial initiative, adopt stimulatory economic policies, and if both researchers and extension workers leave their cloistered laboratories, experiment stations, and offices and put science and technology to work at the farm level. In the short term, better use of existing technology is the answer to accelerate food production in these two countries while the public and private research entities try to unlock the potentials of molecular genetics and biotechnology.

The World Food Production/Distribution Dilemma

There are two key problems involved in feeding the world's people. The first is the complex task of producing sufficient quantities of the desired foods to satisfy needs and to accomplish this Herculean feat in environmentally and economically sustainable ways. The second task, equally or even more daunting, is to distribute food equitably. The impediment to equitable food distribution is poverty — lack of purchasing power — resulting from unemployment or underemployment, which, in turn, is made more severe by rapid population growth.

It is clear that the solution to the world hunger dilemma must come from expanded food production in the low-income countries, where the majority of the world's people live. Moreover, without the development of domestic agriculture and achievement of an adequate and reliable food supply, the development of commerce and industry will be forever retarded.

Satisfying Future Food Demands

According to the Food and Agriculture Organization of the United Nations (FAO), in 1990 global food production of all types stood at about 4.6 billion tonnes of gross tonnage and 2.3 billion tonnes of edible dry matter. Of this total, 98% was produced on the land; plant products constituted 92% of the human diet.

The World Bank predicts that during the 1990s world population will grow by nearly one billion people and then again by another one billion people during the first decade of the 21st century. A medium projection is for world population to reach 6.2 billion by the year 2000 and about 8.3 billion by 2025, before hopefully stabilizing at about 10 billion toward the end of the 21st century.

As in the past, humankind will rely primarily on cereals to supply virtually all of its increased food demand. Even if current per capita food consumption stayed constant, population growth would require that world food production increase by 2.6 billion gross tonnes, or 57%, by 2025, as compared to 1990. However, if diets improve among the hungry poor (estimated to be at least 1 billion people), annual world food demand could increase by 100%, requiring annual harvests of 9 billion gross tonnes, compared with 4.6 billion gross tonnes today. The World Bank reports that South Asia and sub-Saharan Africa are the regions with the most poverty. By the year 2000, South Asia will still have the largest absolute numbers of poor people although sub-Saharan Africa still will have the highest percentage (50% of the total population) in such adverse circumstances.

Further Increases in Food Production Through Increases in Yield Per Hectare

Using the above population growth rate scenarios and expected changes in per capita cereal demand, the following projections for the cereal crop needs through the year 2025 have been derived. To meet the projected food demands, the average yield of all cereals must be increased by 80% between 1990 and the year 2025. Fortunately, there are still many improved agricultural technologies that can be employed in future years to raise crop yields. There are large "yield gaps" in virtually all low-income, food-deficit developing countries as well as the former Soviet Union and Eastern Europe.

Yields can still be increased by 50%-100% in many areas of Asia, Latin America, the former U.S.S.R., and Eastern Europe, and by 100%-200% in much of sub-Saharan Africa. Such productivity gains can be achieved by improving efficiency all along the crop production line, beginning with better land preparation to ensure optimum croplands; more timely planting of the very best available varieties; proper fertilization; and improved control over menacing weeds, diseases, and insects. Of course, as yields become higher, it will become even more important to ensure proper nutrient balances and conserve soil moisture under rainfed agriculture, or if under irrigation, better water management.

Increasing Food Production by Expanding Cultivated Area

Most of the opportunities for opening new agricultural land to cultivation have already been exploited. This is certainly true for densely populated Asia and Europe. Only in sub-Saharan Africa and South America do large unexploited tracts exist, and only some of this land should eventually come into agricultural production. But in populous Asia, home to half of the world's people, there is very little uncultivated land left to bring under the plow.

One of the Last Frontiers: The Brazilian Cerrado

Bringing the world's unexploited potentially arable lands into agricultural production poses formidable challenges. The Brazilian Cerrado, or savanna, is a good case in point.

The Cerrado is a vast expanse of mostly flat to slightly rolling grasslands, with fire-induced semi-climax brush and stunted-tree ecotypes in some areas. Its total area is about 205 million ha, approximately equivalent to the combined area of Spain, France, Italy, and Britain. Today there is new frontier spirit of enthusiasm emerging in the Cerrado, as the potential agricultural giant begins to awaken. But how was research organized to permit this to happen? It has been a slow, painful process. By the second half of the 1960s, farming was being attempted in some parts of the Cerrado on a commercial scale as soil amendments began to be applied — liming to correct acidity and aluminum toxicity, combined with application of nitrogen, phosphorus, and potassium along with micronutrients. A new generation of crop varieties (forage grasses, rice, soybean, wheat, and maize) was developed that possessed tolerance to aluminum toxicity.

One of the last frontiers—the Brazilian Cerrado. IFDC is collaborating with national institutions in Brazil to develop and evaluate sustainable agricultural production systems. Crop models are being used in the Cerrado to study the fate of nutrients added to the soil in the form of pasture and crop residues and animal wastes.

The creation in 1973 of the Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA), the national Brazilian Agricultural Research Corporation, provided a major impetus to research aimed at the Cerrado. EMBRAPA scientists initiated a more coordinated systematic program of interdisciplinary research, integrating past knowledge and generating new research information and products.

In all probability, some of the crop varieties and crop management technologies being developed for the Cerrado will be of considerable value in opening to agricultural production, areas in other regions with similar soil problems, such as the vast plains (Llanos) in Colombia and Venezuela and in central and southern Africa.

African Agriculture in Crisis

More than any other region of the world, agriculture south of the Sahara is in crisis. High rates of population growth and little application of improved production technology have resulted in declining per capita food production, escalating food deficits, and deteriorating nutritional levels, especially among the rural poor. Unless recent production trends are drastically altered, sub-Saharan Africa will only be producing 75% of its food requirements by the year 2000.

Sub-Saharan Africa's extreme poverty, poor soils, uncertain rainfall, increasing population pressures, changing ownership pattern for land and cattle, political and social turmoil, shortages of trained agriculturalists, and weak research and technology delivery systems, all make agricultural improvements difficult. But we should also realize that to a considerable extent the present food crisis is the result of the longtime neglect of agriculture by political leaders. Even though agriculture provides a livelihood to 70%-85% of the people in most countries, agricultural and rural development has been given low priority. Investments in distribution and marketing systems and in agricultural research and education are woefully inadequate. Furthermore, many governments have pursued and continue to pursue a policy of providing cheap food for the politically volatile urban dwellers at the expense of production incentives for farmers.

Many of the lowland tropical environments, especially the forest and transition areas, are fragile ecological systems, where deeply weathered, acidic soils lose fertility rapidly under repeated cultivation. Traditionally, slash-and-burn shifting cultivation and complex cropping patterns permitted low-yielding but relatively stable food production. Expanding populations and food requirements have pushed farmers onto more marginal lands and also have led to a shortening in the bush/fallow periods previously used to restore soil fertility. With more continuous cropping on the rise, organic material and nitrogen are being rapidly depleted while phosphorus and other nutrient reserves are being depleted slowly but steadily.

Since 1986 I have been involved in food crop production technology transfer projects in sub-Saharan Africa, sponsored by the Sasakawa Foundation and its Chairman, Mr. Ryoichi Sasakawa, and enthusiastically supported by former U.S. President Jimmy Carter. Our joint program is known as Sasakawa-Global 2000, and currently operates in six African countries: Ghana, Benin, Togo, Nigeria, Tanzania and, most recently, in Ethiopia. Previously, we also operated similar projects in Sudan and Zambia.

The heart of these projects has been dynamic field testing and demonstration programs for major food crops in which improved technology had been developed by national and international research organizations, but for various reasons, was not being adequately extended among farmers. Working with national extension services during the past 7 years, more than 150,000 one-acre production test plots have been grown by small-scale farmers. Most of these test plots have been concerned with demonstrating improved technology for basic food crops: maize, sorghum, wheat, cassava, and grain legumes. The packages of recommended production technology include: (1) the use of the best available commercial varieties or hybrids, (2) proper land preparation and seeding to achieve good stand establishment, (3) proper application of the appropriate fertilizers and, when needed, crop protection chemicals, (4) timely weed control, and (5) moisture conservation and/or better water use if under irrigation. Virtually without exception, yields of the production test plots are two to three times higher, and occasionally four times higher, than the control plots employing the farmers' traditional methods.

Despite the formidable challenges in Africa, the elements that worked in Latin America and Asia will also work there. If effective seed and fertilizer supply and marketing systems are developed, the nations of sub-Saharan Africa can make great strides in improving the nutritional and economic well-being of their desperately poor populations.

The Environmental Challenges of Developing Countries

In sharp contrast to the rich countries, where most environmental challenges are urban, industrial, and a consequence of high incomes, the critical environmental challenges in most of the low-income developing countries are rural, agricultural and poverty-based. About half of the world's poor live in rural areas that are environmentally fragile, and they rely on natural resources over which they have little legal control. Land-hungry farmers resort to cultivating unsuitable areas, such as erosion-prone hillsides, semiarid areas where soil degradation is rapid, and tropical forests where crop yields on cleared fields drop sharply after just a few years.

Some agricultural professionals contend that small-scale peasant food producers can be lifted out of poverty without the use of modern agricultural inputs, such as improved seed, fertilizer, and agricultural chemicals. They envision efficient crop production systems that are based on organic fertilizers; require little or no chemical fertilizer; rely on farmer-maintained indigenous varieties rather than those improved through science; practice only biological or mechanical control of weeds, diseases, and pests; and use only human power to carry out all farm operations. In our experience, small-scale farmers are reluctant to adopt such "low-input, low output" technologies since they tend to perpetuate human drudgery and risk of hunger; nor do we think that such technologies are environmentally sustainable.

Small-scale farmers are reluctant to adopt "low-input, low output" technologies since they tend to perpetuate human drudgery and risk of hunger...

The Way Ahead

The ignorance of the average citizen about the critical need for fertilizer and the enormous benefits it has brought to humankind is both appalling and abominable. A major educational campaign is needed to inform the public of these issues.

In many developing countries, and especially in sub-Saharan Africa, correct information on proper procedures for fertilizer use needs to be made available to farmers. A huge training job needs to be done with fertilizer dealers to develop their technical understanding of the products they sell and their business ethics toward the farmer.

One of the great hallmarks of developed market economies has been efficient agricultural research and technology delivery systems in which private sector organizations play a major role in supplying information, inputs, and services to farmers. In contrast, most developing nations and the former centrally planned communist block countries have tried to rely on publicly funded organizations to deliver improved technologies to farmers without much success. Plagued by many bureaucratic inefficiencies, public sector organizations have failed to deliver improved seed, fertilizers, and other inputs cost effectively.

Most developing-country governments are looking for ways to get out of the business of supplying inputs, machinery, and other services to farmers and turn these responsibilities over to private sector entrepreneurs and subject them to the controls imposed by competition in an open market economy.

This is a time for the world fertilizer (and seed) industry to ensure the development of efficient delivery systems for an ever-improving array of agricultural inputs throughout the world. In the case of South Asia and the formerly centrally planned economies, privatization involves transforming large public sector organizations into private businesses. However, in the case of most sub-Sahara African countries, little public sector fertilizer activity exists (with the exception of Nigeria). Here a dynamic, private fertilizer sector must be built from scratch. In particular, sub-Saharan Africa, the region facing the greatest

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food insecurity now and in the foreseeable future, needs the support and assistance of all those organizations involved in the fertilizer sector.

Summing Up

The only way for agriculture to produce sufficient food, to keep pace with population, and to alleviate the hunger of the world's poor is to increase the intensity of agricultural production in those ecologies that lend themselves to intensification while decreasing the intensity of production in the more fragile ecologies.

Most of the increases in food production needed over the next several generations must be achieved through yield increases on land now under cultivation. Moreover, these yield increases must be achieved through the application of technology already available or well advanced in the research pipeline. This will not only lead to economic development but also it will do much to solve the serious environmental problems that result from trying to cultivate lands that are not suited to crop production. Fortunately, many of the more favored agricultural lands currently under cultivation are still producing food at yield levels far below their potential.

Given present scientific know-how, the use of chemical fertilizers must be expanded two- to threefold to maintain soil fertility and productivity in developing countries over the next 20 years if the world is to feed itself. Of course, the greatest need is in sub-Saharan Africa, which faces the horrifying prospect of producing only 75% of its food requirements by the year 2000, unless fertilizer use is tripled and combined with higher yielding varieties and improved crop management practices. Surely, raising the average use of plant nutrients from less than 10 kg/ha to something like 30 kg/ha cannot be an environmental problem — only an environmental solution. Fertilizer use also must be expanded in Latin America, especially in the favored lands of Argentina, Brazil, and Uruguay, and in South Asia, where the Green Revolution appears to have lost its momentum.

To achieve the needed production increases and to distribute the food equitably in the low-income, food-deficit countries will require the sustained and focused support of governments, international development agencies, and the private agribusiness sector. This task will not and cannot be achieved without major new investments in the agricultural sectors of the developing countries, particularly in the areas of transportation, fertilizer and seed supply, and water resource development.

At the closure of the Rio Summit, 425 members of the scientific and intellectual community presented to the Heads of State and Government what is now being called the Heidelberg Appeal. Since then, some 3,000 scientists have signed. The last paragraph of the Appeal reads as follows:

> The greatest evils which stalk our Earth are ignorance and oppression, and not Science, Technology, and Industry, whose instruments, when adequately managed, are indispensable tools of a future shaped by Humanity, by itself and for itself, in overcoming major problems like overpopulation, starvation and worldwide diseases.

For those of us on the food production front, let us all remember that world peace will not and cannot be built on empty stomachs. Deny farmers access to modern factors of production, such as improved varieties, fertilizers, and crop protection chemicals, and the world will be doomed, not from poisoning, as some say, but from starvation and social chaos.

The Relevance of IFDC's Work to Dr. Borlaug's Concerns

by

Dr. Carlos A. Baanante, Director, Research and Development Division; Dr. A. Uzo Mokwunye, Director, IFDC-Africa; and Mr. James J. Schultz, Director, Outreach Division

Several concerns that Dr. Borlaug mentions in his essay are issues that IFDC has been applying its resources toward resolving during the past two decades. Some of these issues include the expansion of agriculture to unexploited, potentially arable lands such as the Brazilian Cerrado and the vast plains of Colombia; the challenges confronted by African agriculture; and the need for technical guidance as countries convert from centrally planned economies to open market economies. The following is a brief discussion of how IFDC is addressing these three concerns of Dr. Borlaug.

IFDC's Work in the Colombian Llanos and Brazilian Cerrado

The tropical savannas of Brazil, Colombia, Venezuela, and Bolivia represent one of the last agricultural frontiers on Earth. Together they occupy more than 250 million ha of which an estimated 45 million is suitable for agriculture. Population growth in South America has resulted in the expansion of agriculture to large previously uncultivated areas of the savannas and forest margins. It has been hypothesized that development of the savannas could reduce pressure on the Amazon rain forest and provide a cheaper source of food for the continent's poor, 60% of whom reside in the large overcrowded sections of South America's major cities.

Development of the acid soil savannas requires a systems approach if the goal of sustainable agriculture is to be achieved. In general, savanna soils have very good physical characteristics under native vegetation. However, experience on the Brazilian Cerrado has shown that these soils are extremely fragile when cultivated. Low nutrient reserves, high acidity, and high phosphorus fixation capacity are the main chemical constraints of savanna soils. Thus, nutrient inputs and systems that preserve the soil's physical properties are essential if these soils are to be brought under more intensive agricultural production on a sustainable basis.

To apply its expertise in nutrient dynamics and nutrient use efficiency in the savannas of South America, IFDC is collaborating with national and international partners in Colombia, Brazil, and Uruguay in the development and evaluation of sustainable agricultural production systems. These systems should preserve the soil resource base and use nutrient inputs more efficiently while minimizing their effect on the environment. In Colombia, IFDC is working with Centro Internacional de Agricultura Tropical (CIAT) and the national agricultural research center, Corporación Centro de Investigaciones Agropecuarias (CORPOICA), in implementing a long-term, large-scale experiment and associated satellite experiments on the Llanos. These experiments are comparing the effects of monocultures and rotations involving cereals with grain legumes, green manures, and improved pastures on the soil physical properties, soil biological activity, and nutrient cycling and use efficiency. IFDC is applying its expertise in modeling to crops in these systems and eventually aims to model the systems themselves by coupling component crop models. The use of these models to extrapolate the results of these experiments to more diverse environments is the desired result of this work.

Models are also being used in the Cerrado to study the fate of nutrients added to the soil in the form of pasture and crop residues and animal wastes. One particularly useful model in this work is CENTURY, a model designed specifically to study the decomposition of these materials in the soil and the availability to crops of the nutrients that are released by this process.

Chemical fertilizers are an essential component of the sustainability of any agricultural system. Nutrients can be removed in agricultural produce or lost through the leaks that are present in even the most efficiently cycling production systems. When these lost nutrients are not replaced through external sources, crop production declines, organic matter inputs to agricultural soils fall, soil cover is reduced, and the resource inevitably begins to degrade. The implications of this degradation go beyond its effects on the farmer and the environment; it affects the future potential of the soil resource to produce the food that will feed future generations. IFDC's role in preventing this catastrophe lies in promoting the efficient use of nutrients in a systems context with its partners in national and international agricultural research.

IFDC's Involvement in African Agricultural Development

The establishment of IFDC-Africa in Lomé, Togo, in 1987 manifests the commitment of IFDC to ensure that fertilizer-use technology is made available to West African farmers — the resource-poor farmers who are both the agents and victims of declining soil fertility and environmental degradation. IFDC-Africa's mission is to build national capacities to increase sustainable agricultural production and farmers' incomes while conserving natural resources and protecting the environment through:

- Empowering farmers and national research and extension personnel to develop and adopt environmentally sound fertilizer-use practices.
- Helping West African governments as they change from being managers and controllers of fertilizer procurement, distribution, and sales to being facilitators of competitive, private fertilizer procurement and marketing. IFDC-Africa encourages the creation of national integrated soil fertility management units whose task is to evolve and implement a set of integrated soil fertility restoration and maintenance strategies and harmonize and give direction to national efforts in fertilizer research, policy reform and market development.

During the past 6 years—

- IFDC-Africa has become a major instrument of regional integration by taking the lead to develop and implement projects in both Francophone and Anglophone West Africa. One such project is the Market Research and Development Project, part of IFDC-Africa's Policy Reform, Market Research and Development Program, involving collaborators from both the public and private sectors in over 20 countries in sub-Saharan Africa. Through this project, vital fertilizer market information is made available to both the public and private fertilizer sectors through the publication of a monthly "African Fertilizer Market."
- Agricultural development founded on sound natural resource management is sustainable. IFDC-Africa's Watershed Management Program adopts an integrated and broad-based approach to resolving rural development challenges. The Soil Fertility Restoration Project, carried out in six villages in Ghana, Togo, and Niger, involved work with 800 male and female farmers and 138 national research and extension staff in the three countries on the buildup of soil fertility through the use of fertilizers, local phosphate rocks, and manure. A participatory approach was adopted for the development and adaptation of

appropriate technologies to meet farmers' needs and circumstances.

Yes, agriculture in sub-Saharan Africa is in crisis. The challenges are formidable. IFDC-Africa has, however, made a solid regional impact in West Africa that has earned the respect and confidence of the under-resourced national research and extension systems. Our goal is to co-opt the farmers, research and extension workers, policymakers, and development agencies as partners. Through improved communications between the various groups, we can create a spirit of mutual respect and cooperation that will foster the exchange of skills needed to improve the performance of all partners.

IFDC's Accomplishments in Privatization of Farm Markets

The ultimate goal of the transformation/reform process to open market economies is to improve the efficiency of domestic resource use. Market force economics correspond to private sector-driven efficiency, which, by its very nature, ensures innovative, creative, and competitive resource allocation. During the past few years IFDC has been especially successful in developing policy frameworks and providing technical expertise to guide private sector interventions in the input side of the agricultural production equation. While the process of policy reform is often slow and must be nurtured with a great deal of patience, IFDC's work has resulted in a number of measurable results in projects in Albania, Bangladesh, Egypt, and Romania.

Albania — IFDC transformed a United States Agency for International Development (USAID)-funded emergency fertilizer assistance program involving 30,000 tonnes of fertilizer into a free market experience by auctioning the fertilizer to Albanian entrepreneurs who, in turn, marketed it to the farmers through a newly emerging corps of private agri-inputs retailers. The majority of the fertilizer was sold at or near market prices. Additionally, IFDC assisted in developing the banking sector and the opening of credit channels between the banks and private sector entrepreneurs. The success of this initiative was confirmed during the first quarter of 1994 when the Albanian private dealers, using their own resources, imported and marketed about 20,000 tonnes of fertilizer, having a value of about US $4 million. IFDC was also instrumental in bringing about the Government's decision to decrease the import tax on fertilizers, thus improving competitiveness in the domestic marketplace.

Bangladesh — IFDC entered Bangladesh almost 15 years ago with a relatively modest USAID-funded project designed to improve the efficiency of the state-owned fertilizer distribution system. This early initiative led to an expanded project that is often cited as a reference to illustrate the importance of policy reform in bringing about private sector entry into the marketing and distribution of fertilizer and other agricultural inputs. Today essentially all fertilizer, domestic production and imports, is marketed by the private sector without subsidy. Concurrent with this change, during the last 4 years of market-driven reform, fertilizer use remained relatively steady despite increased prices, and the country became self-sufficient in cereal production during the same period. The success in Bangladesh is attributed in part to the long-term commitment and persistence of IFDC, the Government of Bangladesh, and USAID in developing the concepts of liberalization and market reform.

Egypt — Liberalization in the Egyptian fertilizer sector began in 1986. As a result, an urgent need to develop the technical, marketing, and business skills of those in the emerging private sector became apparent. In 1993 in response to this need, IFDC provided a comprehensive program designed to "train the trainer" in marketing, business, and technical skills, including such specific technical topics as the safe handling of agricultural chemicals and other inputs. Approximately 60 "trainers" were recruited from the Egyptian public and private sector and developed by IFDC. These trainers then carried the program forward to their dealers and retailers, thus quickly enlarging the knowledge base at the retail level, which was so urgently needed to serve the needs of farmers.

Romania — In 1993 using 17,000 tonnes of USAID grant-funded high protein animal feed supplement as the commodity, IFDC began to mirror the Albanian experience and used the feed supplement to begin the development of a private animal feed and agri-inputs sector. In concert with this, IFDC also began to work with the private swine and poultry producers to develop skills in processing and marketing of their output, thus decreasing their dependence on the sale of their output exclusively to the state at regulated prices. This transition, while still in its infant stage, is developing rapidly and the scope is large since about 50% of Romania's swine production is in the hands of the private farm sector, which continues to aggressively look for ways to improve its situation.

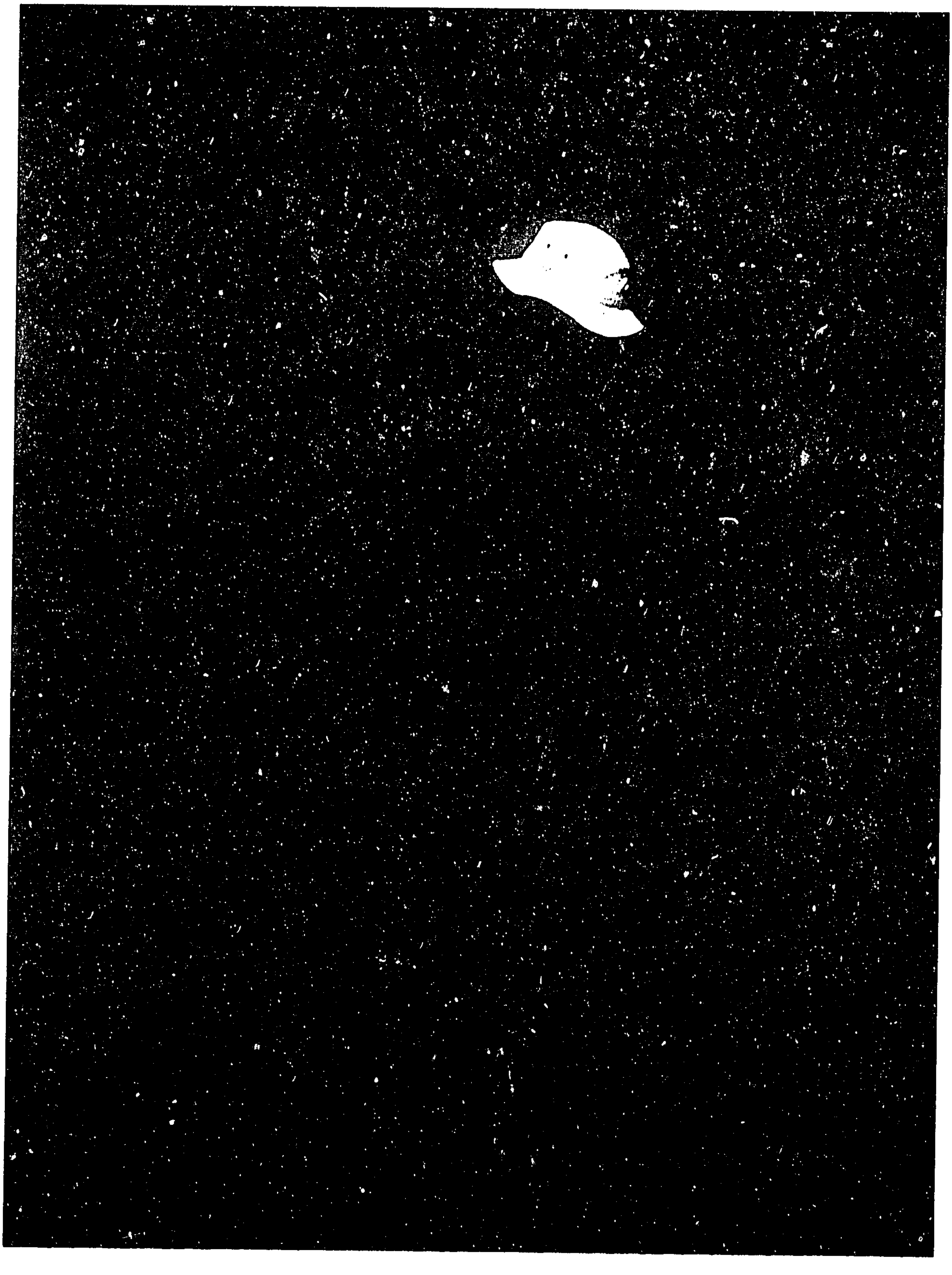
1993 IFDC Highlights

The Promotion of Sustainable Agriculture Through IFDC's Nutrient Dynamics Research

Introduction

During this decade an important component of IFDC's work deals with nutrient dynamics, balances, and the role of fertilizer in farming systems that will enable developing nations to expand and sustain agricultural production using both inorganic and organic sources of plant nutrients. IFDC is leading a major scientific effort to integrate nutrient cycling studies with overall crop modeling activities. The findings of this research are being translated into applied results on the farms of the tropics and subtropics. The ultimate goal of this work is to increase the efficient production, marketing, distribution, and use of plant nutrients for the economic growth of nations. This research is conducted in cooperation with nongovernmental organizations (NGOs); national agricultural research systems (NARS) in Africa, Asia, and Latin America; and other international agricultural research centers.

Dr. Dennis K. Friesen, IFDC Soil Fertility Scientist, posted at CIAT in Colombia, is collaborating with scientists at that center to study the biophysical and agronomic processes that contribute to sustainability or lack thereof in a spectrum of alternative production systems in the tropical savannas of Latin America.



Highlights of 1993 Achievements

Integrated Nutrient Management for Resource-Poor Rice Farmers in India

Small-scale resource-poor rice farmers in India grow rainfed transplanted rice during the monsoon season. Because of socioeconomic limitations, agroclimatic constraints, and traditional cultivation practices, yields in their small paddy fields are low (1-2 tonnes/ha). These farmers number in the millions; thus, they have the potential of substantially increasing India's rice production if they can increase productivity of their fields by as little as 500 kg/ha. To help these farmers, not only in India but in all of south and southeast Asia, an IFDC scientist has developed a system of integrated nutrient management for their use to increase rice productivity in a sustainable manner (IFDC Annual Reports for 1989, 1990, and 1992). This technology consists of a crop cultivation system that integrates efficient use of soil and applied plant nutrients with appropriately modified agronomic and pest management practices that help to increase and sustain crop productivity while protecting the environment over a long period of time.

In collaboration with several NGOs in India, an IFDC researcher continued field research on these crop production systems during 1993. The main results of the 1993 field trials are summarized below.

Recycling of Plant Nutrients — The practice of applying rice hull ash as a source of silicon to a rice nursery for the preparation of healthy seedlings basically addresses two sustainability concepts related to rice farming. They are: (1) recycling of plant silicon — a beneficial nutrient for rice — and (2) reducing the incidence of stem borer and leaf blast in the early stages of plant growth without the use of chemical pesticides, thus helping to protect the environment. Additionally, the practice has an indirect potential environmental benefit. If small rice farmers use rice hull-fired stoves for domestic cooking, they will be using a renewable alternative energy source (rice hulls — an agricultural waste — rather than firewood). Thus, the practice has the potential of protecting existing forest trees in traditional rice-growing areas.

The results of the 1993 field trials supported the 1991/92 beneficial effects of the application of rice hull ash (0.5-2 kg/m^2) to the seedbed by reducing the incidence of stem borer damage in transplanted rice. The results of the 1993 greenhouse experiment confirmed a natural protective effect of the application of rice hull ash observed in 1992, and the rice seedlings of the highly susceptible variety EK-70 were almost resistant to leaf blast up to 30-45 days after sowing.

In the practice of incorporating limited rice straw before transplanting, the amount of rice straw as a source of potassium and silicon to be recycled has been limited to 2 tonnes/ha (as opposed to 5-10 tonnes/ha normally used as a source of organic matter or nitrogen) to minimize its contribution to greenhouse gas emissions. The main objective of the practice is to enable small rice farmers to use crop residues to supply 30-40 kg potassium/ha, thereby ensuring balanced nutrition for rice crops — a requirement of sustainable crop production. Collaborative field trials conducted in 1993 supported the positive effect on rice yields of basally incorporating rice straw with applied nitrogen (as prilled urea or urea briquettes), which was observed in the 1992 field trials. Based on the results of 1992/93 trials, the incorporation of rice straw increased yields by 20% in grain and 12% in straw.

Limited Gliricidia Green Manuring — An agroforestry approach of growing gliricidia (biologically nitrogen-fixing) trees on bunds, hedges, and/or nearby noncultivated land and using their leaves (green leaf biomass) for green manuring offers a potential affordable practice for the integrated use of organic manures and fertilizers in rice. In 1989 collaborative field trials began testing this practice (2-3 tonnes of green leaf biomass/ha) in rainfed transplanted rice in India. The results of the 1993 field trial confirmed the beneficial effect of the integrated use of gliricidia green manuring with urea (as urea briquettes) in transplanted rice, and additional yields up to 21% in grain and 15% in straw were recorded in an Alfisol.

Controlling Plant Population — To date, resource-poor farmers are unable to realize the full yield potential of fertilizer-responsive high-yielding varieties (HYVs) that brought about the green revolution in rice in developing Asian countries. Two constraints — traditional methods of random transplanting that do not achieve adequate plant population and inefficient methods of fertilizer application — cause the low yields.

To overcome these constraints, an IFDC scientist working in collaboration with rice agronomists in India designed two methods of line transplanting that enable them to control plant population in the field. These methods include the bamboo transplanting guide method and the two-row transplanting method (IFDC Annual Reports, 1989 and 1990).

In the 1993 field trials, when the participating farmers integrated the use of these transplanting methods with an efficient fertilizer use method (described below), they harvested an average additional grain yield of 1.5 tonnes/ha (a 52% increase) at 56% lower plant population as compared with the traditional method of transplanting and conventional method of fertilizer application.

Environmentally Sound Fertilizer Use—The inefficient use of fertilizers is one of the main reasons for lower rice productivity of paddy fields during the monsoon season, and serious losses of applied nutrients via runoff waters that cause environmental concern. Therefore, an IFDC scientist has collaborated with NARS in India to develop an improved fertilizer management practice that is agronomically efficient and economically attractive to small rice farmers. It is environmentally sound because it substantially reduces losses of applied plant nutrients. The practice consists of deep placement of urea briquettes containing diammonium phosphate by hand at 1 briquette/4 hills immediately after transplanting with 25 hills/m^2 and modified 20 x 20 cm spacing.

During the 1993 wet season, 26 farmer-participatory trials were conducted on fields of tribal rice farmers. The results of these trials clearly demonstrate the superiority of the improved fertilizer use practice over the conventional practice of split application of prilled urea and basal application of single superphosphate (SSP) and over the farmers' traditional practices (Figure 1). By

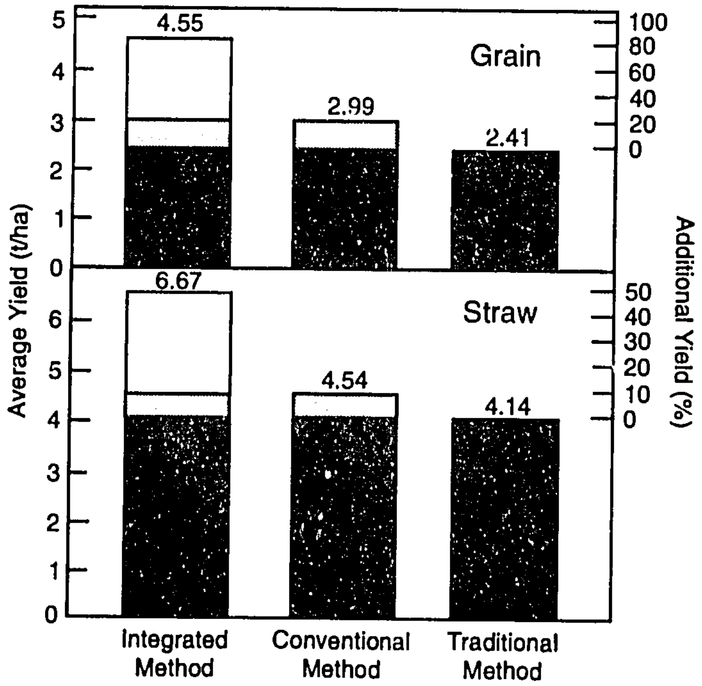


Figure 1. Improved Rice Productivity Due to Use of Single Deep Placement of UB-DAP After Transplanting (Integrated Method) as Compared With Split Application of Prilled Urea + Basal Application of Single Superphosphate (Conventional Method) and Practically No Fertilizer Use (Traditional Farmers' Method). IFDC/NGO Field Trials, 1994.

Source: Daftarder and Savant (1994).

using modified spacing, workers increased their speed of urea briquette placement by hand and therefore decreased the labor requirement by as much as 50%.

The four components of the integrated nutrient management technology are flexible. With minor modifications and limited field testing for one to two seasons, this technology could be adapted and transferred to a given agroclimatic region of other developing countries.

Nutrient Management for Rice-Based Cropping Systems in Southeast Asia

The need to continue increasing rice production is evident from the facts that: (1) 100 million additional people must be fed every year, (2) rice is the staple food for half the world, (3) more than 90% of the world's rice is grown and consumed in Asia, and (4) 65% of the world's poor are Asians. The increased production, however, must not occur at social and environmental costs. In developed countries, where the application of inorganic fertilizers ranges from 300 to 800 kg/ha, environmental contamination has been attributed to fertilizer use. In developing countries, judicious input of inorganic fertilizers is essential for productive and sustainable cropping systems. The collaboration between the International Rice Research Institute (IRRI) and IFDC focuses on maximizing rice productivity and reducing environmental contamination through the sustainable use of resources. Past emphasis has been on reducing nutrient losses, and that remains a priority. In addition, another area of focus is improving the efficiency of applied nutrients and those already in the soil of flooded rice fields by (1) synchronizing nutrient supply with plant demand, (2) identifying nutrient-use efficient cultivars, and (3) achieving balanced nutrient availability. The research, however, is not limited to flooded rice because management of fallow crop after rice is critical in terms of nitrogen loss, both economically and environmentally. To improve the explanatory and extrapolative use of field data, the research is closely linked with simulation modeling. The field research also has an underlying objective of generating knowledge-gap information to improve the existing rice and nutrient dynamics models.

Modifying Nitrogen Availability — Urea, the principal source of nitrogen fertilizer in rice production, is often not used effectively by the rice crop. Strategies have been developed to increase the efficiency of applied nitrogen fertilizer, including modifications of urea fertilizer products, deep placement, and proper timing of nitrogen fertilizer application at a time that best meets the demand of the rice crop. Because deep placement of urea supergranules (USG) reduces volatilization losses, it extends the period of availability of applied nitrogen by continuously supplying that nutrient to the rice crop throughout the entire growth period.

Field experiments were conducted for two seasons (1992 wet and 1993 dry) at a newly developed IRRI field. IFDC scientists wanted to determine if yields could be increased by combining deep-point placed USG with different rates of urea applied basally. The experiment consisted of 18 nitrogen fertilizer treatment combinations and four replications with optimum rates of phosphorus, potassium, and zinc. USG was deep-point placed at transplanting; USG deep-point placement was combined with applied prilled urea, which was incorporated into soil at transplanting; and prilled urea splits were applied at different growth stages (basal, 15 days after transplanting, 5-7 days after panicle initiation, and at heading). IR72 was the variety used in the experiment. The results from only the 1992 wet season and the 1993 dry season experiments are discussed.

The optimum nitrogen rate to achieve high yield in the wet season was 87 kg USG. Total nitrogen uptake was highest with increasing nitrogen rates (145 and 203 kg nitrogen/ha). Dry season results showed that plants responded to a higher addition of nitrogen.

Total nitrogen uptake was observed to be consistently higher in the wet than in the dry season despite lower total biomass in the wet season. This observation may be attributed to higher contribution of soil available nitrogen (data not shown) as a result of the fallow environment before the commencement of the experiment. Agronomic efficiency (kg increase in grain yield over control per kg nitrogen applied) values in the 1992 wet season were generally lower than those of the 1993 dry season. Apparent recovery (kg increase in nitrogen uptake over control per kg nitrogen applied x 100) values of applied fertilizer were significantly higher in the wet season than in the dry season.

Recommendations for proper nitrogen management in a flooded soil during both wet and dry seasons should therefore consider not only timing and rates of nitrogen applied but also sources. Higher levels of nitrogen may lead to excessive biomass production but without increase in grain yield and even decrease in grain yield. Much of the research in the past with nitrogen sources and timing with respect to losses and recovery had been done in the dry season whereas most rice is grown during the wet season. Floodwater and ^{15}N data are still being analyzed to confirm whether losses are much lower in the wet season.

Genotypic Variability in Nitrogen Uptake and Utilization — The focus of this research between the Soil and Water Science Division of IRRI and IFDC was to identify genotypes that have higher acquisition and improved usage of native soil nitrogen and applied nitrogen. These genotypic differences may arise due to differences in subsoil nitrogen, effect of rice cultivars on rhizospheric nitrogen fixation and mineralization, and efficient use of absorbed nitrogen. Additionally, the study provided an opportunity to generate genetic coefficients for the CERES-Rice Model. A total of 180 genotypes — 60 early duration (100-110 days), 60 medium duration (111-120 days), and 60 late duration (121-135 days) — were included. The 2-year experiment was conducted at the IRRI farm with available soil ammonium content in a 0- to 20-cm layer of 48 kg nitrogen/ha in the first year and 33 kg nitrogen/ha in the following year. No additional nitrogen fertilizer was applied.

Depleted soil nitrogen in 1992 (second year) resulted in significant changes in plant parameters. The parameters most stable to changes in soil nitrogen were percent of straw nitrogen at maturity, 1,000 grain weight, and filled spikelets per panicle. For these parameters less than 20% of the genotypes showed significant changes between the 2 years.

In the CERES-Rice Model, 1,000 grain weight is a genotype-specific coefficient. The model assumes that all rice genotypes have identical critical nitrogen concentration with growth stages. The preliminary results from the study indicate that there may be significant differences in critical nitrogen concentration among genotypes. There is also evidence to include root traits as genotype-specific coefficients.

The data from this study are being reanalyzed, and additional field trials are underway to confirm genotypic differences among rice varieties with similar growth duration.

Nutrient Management for Sustainable Agriculture on Acid Soils of Latin America

In 1992 IFDC joined CIAT in a project to develop sustainable agropastoral and sequential cropping systems for the tropical savannas of Latin America. This ecosystem is dominated by highly acidic and infertile soils (Oxisols and Ultisols), which have properties that are not conducive to the efficient use of nutrient inputs. If these soils are to be used on a more intensive and sustainable basis for food production, nutrient inputs are essential. However, efficient use of these nutrients is imperative from both an economic and environmental perspective.

In 1993 IFDC and CIAT established a major long-term experiment on the Colombian Llanos to study the biophysical and agronomic processes that contribute to sustainability or lack of sustainability in a spectrum of alternative production systems ranging from monocultures through cereal-legume rotations to agropastoral systems. The choice of system components was based on (1) whether lime is applied as a fertilizer (to supply calcium and magnesium to aluminum-tolerant crop and pasture species) or (2) as a soil acidity ameliorant (to enable production of more aluminum-sensitive species). The "fertilizer lime" systems are based on CIAT's aluminum-tolerant upland rice line, Sabanas-6, with adapted legumes and pasture species, while the "remedial lime" systems are based on maize with less-adapted legume and pasture germplasm. The experiment is designed with plots that are sufficiently large to permit grazing and the use of conventional machinery, both of which are likely to influence soil physical properties. IFDC's responsibility focuses on understanding the mechanisms of nutrient loss and nutrient cycling to improve nutrient use efficiency in these production systems. Incorporation of this knowledge into simulation models of crop and nutrient dynamics (such as the CERES models) will enable the extrapolation of these systems across a wider range of agroclimatic environments.

IFDC's responsibility focuses on understanding the mechanisms of nutrient loss and nutrient cycling to improve nutrient use efficiency in crop production systems.

Belisario Volveras, a CIAT assistant in the tropical lowlands program, inspects a pioneer rice crop in a CIAT/IFDC collaborative long-term crop/pasture rotation experiment, being conducted in Carimagua, Colombia.

"Fertilizer lime" rotations were implemented in 1993. The rice crop yielded approximately 3.5 tonnes/ha and in the agropastoral system left a well-established legume-based pasture that was ready for grazing 3 months later. "Remedial lime" rotations will be implemented in 1994. Satellite experiments are being used to determine optimal nutrient requirements for component crops and to examine nutrient dynamics and interactions in more detail than is possible in the main experiment. Among the issues being examined are (1) the balanced use of lime, magnesium, and potassium; (2) the dynamics of phosphorus and the residual effectiveness of phosphate fertilizer applications; and (3) the importance of silicon in rice nutrition on highly weathered soils.

Lime-Magnesium-Potassium Interactions — Because savanna soils are very acidic and have a low capacity to retain plant nutrients, applications of lime, magnesium, and potassium need to be carefully balanced to avoid unfavorable interactions that would lead to nutrient deficiencies, inefficient use of inputs, and exacerbated losses through leaching. Consequently, experiments were established on three different savanna soils during 1993 to (1) determine the optimal balance of lime (calcium), magnesium, and potassium for component crops; (2) study the dynamics and interactions of these plant nutrients; and (3) estimate residual effectiveness of lime, potassium, and magnesium applications and requisite maintenance rates for optimal crop growth.

Although rice grain yields responded strongly to lime (as calcite), potassium, and magnesium, the only significant interaction was between lime and magnesium. However, response to any one nutrient was severely limited by the absence of any one of the others. Maximum yields of about 3,000 kg/ha were reduced to 2,000-2,200 kg/ha without lime while without potassium or magnesium they were reduced to less than 800-1,200 kg/ha. Although lime and magnesium were able to compensate for each other to a degree, yields were virtually nil when neither was applied. In balance, rice on these soils required about 150-300 kg/ha of calcitic lime and 30 kg/ha of magnesium. Taken together, these values indicate a minimal lime application on both soil types of 300 kg/ha as dolomite having a calcium:magnesium ratio of 2:1 to 3:1. Optimal potassium rates depended on soil type; 80 kg/ha was adequate on the heavier soil while 120 kg/ha or more was required on the sandy soil. These data clearly indicate a leaching loss even though the application was split three ways.

Phosphorus Dynamics and Residual Value — Oxisols and Ultisols are often referred to as soils with "high phosphorus-fixation capacity." However, "fixed" phosphorus is often phosphorus that is merely more slowly available, and very substantial residual effects of applied phosphorus have been found on so-called high phosphorus-fixing soils. Quantification of the residual value of previous phosphate fertilizer applications is essential to increase the efficiency of phosphate fertilizer use. Moreover, knowledge of the fate of applied phosphorus is a prerequisite to modeling phosphorus dynamics in soil and its availability to crops. Experiments established in 1993 on highly weathered Llanos soils will determine crop response to applications of phosphate and its effects over a 4-year period. These experiments will provide data for the development of the phosphorus submodels of the CERES crop simulation models. Rice yield response data from the first season demonstrate the fallacy of generalizations regarding the often exaggerated ability of "tropical soils" to fix phosphorus. Although grain yields increased eightfold with phosphate fertilizer, optimal growth (90% of the estimated maximum yield) required 20 kg phosphorus/ha when broadcast and incorporated as soluble phosphate — triple superphosphate (TSP) — at planting (Figure 2). This low

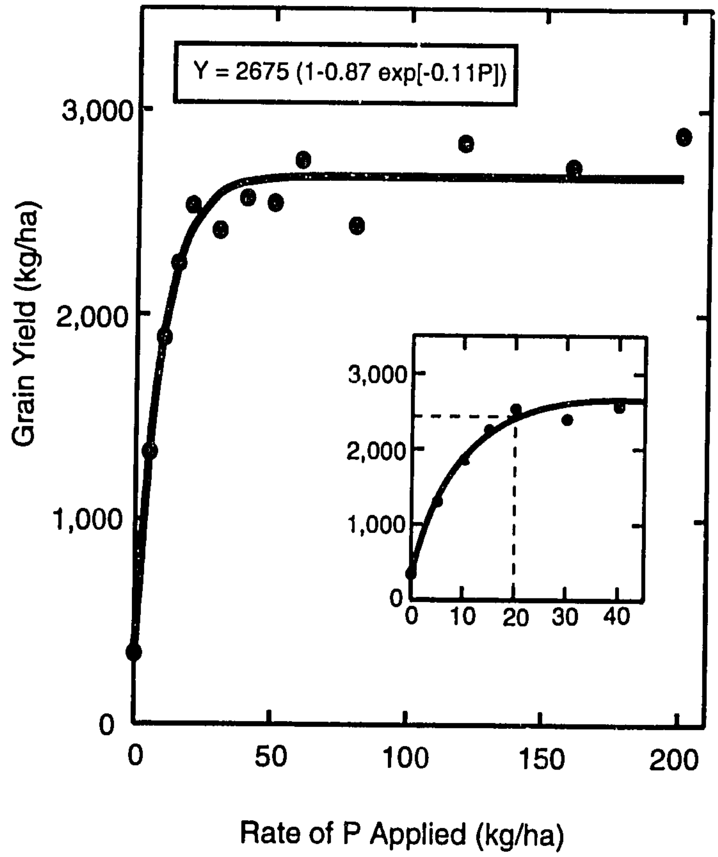


Figure 2. Response of Rice (Sabanas-6) to Rates of Soluble P Fertilizer (TSP) Broadcast and Incorporated at Planting on a Virgin Oxisol at Matazul. (Insert shows optimal P rate to obtain 90% of estimated maximum yield calculated from the Mitscherlich response function.)

requirement may be partially due to inadequate levels of silicon in these soils. However, results for an adjacent trial (see next section) indicate that adequate phosphorus levels for rice do not exceed 50 kg/ha, a rate that cannot be considered typical of a high phosphorus-fixing soil.

Silicon Nutrition of Rice — Inadequate silicon may limit rice yields and increase crop susceptibility to pathogens and disease. Low levels of soluble silicon may be expected in Oxisols and Ultisols since the weathering process essentially involves desilication. Consequently, field experiments on representative soils of the Llanos were established in collaboration with CIAT's Rice Program to determine to what extent silicon constrains rice yields and whether (as the literature suggests) silicon is able to substitute for phosphate fertilizer. Treatments were factorial combinations of silicon as $CaSiO_3$, phosphorus as TSP and rice varieties of contrasting tolerance to silicon deficiency. Application of silicon increased grain yields of both varieties by 600-900 kg/ha on both soils (Figure 3). Rather than reducing the requirement for phosphate fertilizer, response to TSP was greater at higher than at lower levels of silicon. Average grain yields without silicon were approximately 2,500 kg/ha, and there was no response beyond 25 kg phosphorus/ha. With 500 kg silicon/ha, mean yield increased to 3,500 kg/ha, provided the phosphorus rate was increased to 50 kg/ha. Although silicon amendments were highly effective in increasing yields, the viability of this strategy requires identification of economic sources of silicon, or alternatively, identification of rice germplasm that is more efficient at extracting silicon from these soils.

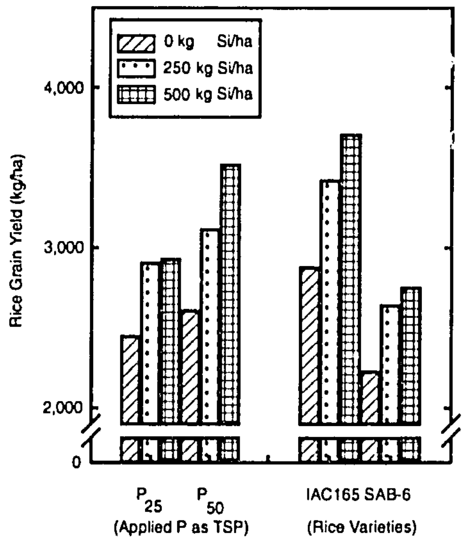


Figure 3. Effect of Silicate Applications to Two Oxisols on Grain Yields of Two Rice Lines at Two Rates of Applied P Fertilizer.

Farm-Level Modeling for Natural Resource Use Planning: A Case Study in Uruguay

Agricultural research and development in developing countries is characterized by two primary concerns. The first concern is to increase agricultural productivity on a sustainable basis, i.e., increased output per unit area of land in ways that minimize damage to the environment and natural resource base. The second concern is that the limited flow of information between farmers, researchers, extension workers, policymakers, and agribusiness personnel is a serious impediment to sustainable development. In addition to these concerns, the complexity of most agro-ecosystems, the necessity of taking a long-term view of biophysical processes, and the limited research resources available emphasize the need for new tools and methodologies to study the problems of sustainable production, to seek solutions, and to assess their impacts at the farm level.

In late 1993 IFDC began a project in Uruguay using modern information tools to help transfer information concerning natural resource use to that country's decisionmakers. The project, partially funded by the Rockefeller Foundation, is using existing farm-level data bases, results of previous field experiments, crop simulation models, a geographic information system (GIS), and an automated land evaluation system.

Simulation models that can predict soil nutrient dynamics and crop growth for different agroeconomic scenarios can contribute much in helping to define crop production strategies that lead to rational use and conservation of natural resources. Crop models, such as the CERES and GRO models, and nutrient dynamic models, such as CENTURY, have been used for predicting the effects of soil properties, water management, weather, and agronomic practices on crop production and nutrient dynamics in several regions of the world. Most of these applications have been carried out at research institutes under relatively controlled conditions. Applications at the farm level are more scarce primarily because of the lack of relevant data required for the calibration and validation of the models.

One source of discrepancy between the crop yields predicted by simulation models and those obtained by farmers is the incidence of plant diseases. The crop yields obtained in research centers where diseases are generally controlled tend to agree well with the predicted yields under the same conditions. The Plant Protection Division of Uruguay has studied the effect of varying degrees of severity of several diseases on crop yields, and IFDC's project will incorporate these results into the simulations at the farm level.

Another potential constraint to the adequate prediction of farmers' yields using simulation models is the variability of existing farming systems. A characterization of such farming systems and a consideration of this variability are expected to result in better predictions by the models.

IFDC is collaborating with the Federación Uruguaya de Grupos CREA (FUCREA), a farmers' nongovernmental organization in Uruguay. FUCREA has collected detailed information on wheat and barley production from more than 2,500 farmers' fields. This data base includes information on tillage, input use, soil analysis, agronomic practices, pest monitoring, grain yields, field size and tenure type, production costs, and output prices. Most of these fields are located in two provinces of Uruguay where most wheat and barley are produced.

Simulation models linked to a GIS can be used by planning agencies to identify regions that are best suited for specific production systems.

Simulation models linked to a GIS can be used by planning agencies to identify regions that are best suited for specific production systems. In order to further improve the planning capability of these agencies, Automated Land Evaluation System (ALES) can be used to build expert systems for evaluating land according to the standard FAO methodology. The application of ALES would allow questions to be answered on land use, such as the most appropriate areas for particular land uses and the most appropriate uses for particular land areas. The evaluation matrix resulting from an application of ALES can also be used as input for a GIS. A key component for the application of the tools outlined above (crop simulation models, GIS, and a land evaluation system) is soils information. The Soil and Water Department of the Uruguayan Ministry of Agriculture has recently completed a digitized map of the soil types for the proposed study region. The map, at a scale of 1:200,000, is linked to a data base with complete records for 67 representative soil profiles of the region.

The mechanics of linking simulation models and land evaluation systems with a GIS poses few problems. However, there is considerable methodology development required before the resultant tool can be routinely applied to perform meaningful impact assessment of agricultural production options at the farm or regional level. Because most of the data required for the project have already been collected, IFDC's activities now involve methodology development and data processing and will constitute a test case for application of the methodology, which can thereafter be developed and applied in other regions.

Evaluation of CENTURY Model in Uruguay and Brazil

Assessing the sustainability of production systems has been a major objective of many national and international agricultural research programs during the past 10 years. The need to consider long time periods when assessing sustainability of agricultural systems imposes a limitation on the research approaches that can be used to accomplish this objective. Thus, the experimental results used to evaluate the sustainability of production strategies should almost always come from long-term experiments and/or from farmers' records for which long-term information is available. Even though they are scarce, there are some very valuable experiments that are still producing excellent information on the long-term effects of different soil and crop management strategies. Conventional analysis of the results from these experiments can be applied to interpret and even predict the long-term effects of similar production strategies under similar conditions. However, these procedures may not be appropriate to predict long-term results of other strategies applied to other conditions.

In these situations reliable computer simulation models play a key role. Simulation models are ideal tools for supplementing conventional research in situations for which the conventional approach is either impossible, too expensive, or impractical. The assessment of agricultural sustainability is a good example of one of these situations. The time periods needed for its assessment are long; therefore, the research is expensive and the results are usually required well before the research can be completed. Moreover, the large number of interacting factors involved in the concept of sustainability prevents the exclusive use of the conventional research approach.

IFDC's activities in Latin America have included the use of data from ongoing long-term experiments and the application of simulation models. One of the most valuable long-term agricultural experiments in Latin America is located at the "La Estanzuela Experimental Station" of the National Agricultural Research Institute (INIA) of Uruguay. The Estanzuela experiment, which was established to evaluate the long-term effects of seven cropping systems with different crop and pasture sequences, has provided very valuable information for the past 30 years. Each crop and pasture sequence is established in large plots (0.5 ha) and is replicated three times. The size of the plots allows for the use of conventional farming equipment, which is similar to the type used by farmers of the region. Complete records of input use, crop and pasture yields, input and output prices, and soil analysis data for the complete time series of the experiment are maintained. The results of the first 30 years of research have shown the advantages of including pastures containing legumes in rotation with agricultural crops. This practice has contributed to maintaining soil productivity with less fertilizer, higher crop yields, and more stable economic performance.

In 1993 IFDC began collaboration with Dr. Alejandro Morón and other staff members of the Soils Department of INIA-La Estanzuela to determine soil carbon levels, nitrogen and phosphorus mineralization rates, crop residue decomposition rates, and soil organic matter fractionation studies. These determinations are intended to produce information on "soil quality" indices, i.e., parameters that can be related to the soil's ability to support sustainable agricultural production systems.

The research results are also being used to calibrate and validate CENTURY, a soil organic matter and nutrient dynamics simulation model. The CENTURY model, developed in the Natural Resource Ecology Laboratory of Colorado State University, simulates the long-term dynamics of carbon, nitrogen, phosphorus, and sulfur for different soil-plant systems. The model simulates the dynamics in grassland systems, agricultural cropping systems, forest systems, and savanna systems. It includes plant production submodels for each of these systems, which are linked to a common soil organic matter submodel. This soil organic matter submodel simulates the flow of nutrients through plant residues and the different organic and inorganic pools in the soil.

The CENTURY model adequately simulated the soil organic matter evolution of the 30-year Estanzuela Rotation Experiment. The model was able to simulate the variations in the soil organic carbon and total nitrogen for three contrasting cropping systems: (1) continuous crops without fertilizers, (2) continuous crops with nitrogen and phosphorus fertilizers, and (3) a system in which pastures containing legumes are grown for 3-4 years, followed by 3-4 years of crops.

Once the CENTURY model has been tested, calibrated, and validated, it may be used for several applications. For example, it can be used to predict the plant nutrient availability in the soil at any given time of a crop sequence and assist in the fertilizer recommendations. The CENTURY model can also be used to evaluate the soil's long-term ability to sustain agricultural systems with different crops, crop sequences, fertilizer inputs, tillage methods, and strategies for soil erosion control. The model can also be used to monitor continuously the evolution of soil properties associated with "soil quality" in existing production systems.

The CENTURY model can also be linked to other models, such as the models developed by the International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT), which are capable of simulating the development and growth of several crops in a detailed fashion. Finally, these models can also be used in conjunction with Geographic Information Systems to build decision support systems that can be extremely powerful tools for local or regional planning.

Currently, IFDC staff members are calibrating and testing the CENTURY model in pasture-based systems of Central Brazil (Cerrados). The Cerrados, covering approximately 200 million ha in Brazil, is a key region for the country's agricultural development. In the Cerrados, 10 million ha is now being planted to crops, and the area is expected to expand dramatically in the near future. Further development of this region may alleviate some of the agricultural and environmental pressures being placed on the Amazonian region.

The CENTURY model will be used in the Cerrados to assist in identifying soil and crop management strategies that would avoid soil degradation problems and result in sustainable production systems. The model would indicate the most viable strategies, which could thereafter be tested under experimental and/or farmers' conditions.

Maize Modeling in Malawi

With funding from the Rockefeller Foundation, a maize modeling initiative was undertaken in Malawi from late 1989 to early 1993. This project involved collaboration between the Malawi Department of Agricultural Research, the University of Edinburgh, and IFDC. The objectives were to assess the suitability of modeling techniques in prioritizing research activities and to use modeling to produce useful information for research and extension activities. CERES-Maize — a model that simulates the growth, development, and yield of maize — was validated for a number of sites in central Malawi. Field trials were carried out on experiment stations and in farmers' fields over three seasons. Yields obtained in the field varied from 0.4 to 6.5 tonnes/ha, depending on treatment (variety and fertilizer application) and season. Simulations with the crop model successfully reproduced these yields.

After the model was validated, it was used to accomplish the following:

- **Investigation of Planting Time Periods** — Optimum planting time periods were identified for the sites where field experiments were run.
- **Identification of Optimal Planting Densities** — Simulation results confirmed that the nationally recommended planting density of 3.7 plants/m^2 for local varieties and 4.4 plants/m^2 for short-statured hybrids, such as MH-16, is well suited for current management systems in Malawi.
- **Nitrogen Fertilizer Management** — Simulated optimum nitrogen application rates based on grain yield for both local and hybrid varieties varied from 80 kg nitrogen/ha at 3.7 plants/m^2 to 150 kg nitrogen/ha at 6.4 plants/m^2. Split nitrogen applications were

found to be beneficial on sandier soils in the region.

- **The Economics of Fertilizer Use** — Simulations using prices and costs for late 1992 indicated that economically optimal applications of fertilizer ranged from 60 to 100 kg nitrogen/ha. Gross margins of fertilized hybrid maize were approximately twice those obtained from fertilized local maize.

Regional Analysis — The linking together of crop simulation models with the spatial data bases of a GIS is a means of performing regional analyses and presenting information to decisionmakers in a form that is easily understood. To illustrate the technology for Malawian conditions, a crop model GIS was constructed for two agroecological zones of central Malawi. In this region most of the soils are deep and well drained but of low or moderate inherent fertility. Land unit, land use, and soil maps produced by FAO were digitized; soils were characterized into soil profiles; and weather records were assembled. CERES-Maize was then run for 20 different weather seasons for each combination of soil type and weather zone. A hybrid maize was planted, and 30 kg/ha urea was applied at planting.

Simulation results were then mapped. Figure 4 shows mean yield of maize per hectare; each mapping unit represents a combination of soil type, weather zone, and land use. Maize yields are mapped only in those areas defined as rainfed agricultural land (the blank areas correspond to built-up areas, rock outcrops, escarpments, grassland, plantation forest, and natural woodland). Mean simulated maize yields varied widely in the region, depending on soil and climate type. Other maps were produced showing the influence of weather variability across the region and nitrogen loss and nitrogen use efficiency. The variability of maize yields regionally is substantial; this results from a combination of soil and weather effects. Certain soil types are also more prone to nitrogen loss, while others exhibit substantial nitrogen use efficiency, in terms of comparatively large increases in maize grain yield for small additions of fertilizer nitrogen.

Such regional analyses using the crop model GIS could be used in a number of ways: identification of areas of low nutrient use efficiency where research might be concentrated to improve it; land suitability studies; derivation of management recommendations by mapping unit; and identification of sites that are representative of larger areas for variety testing, for example. For regional decisionmakers, such a tool could be used to help estimate input use and production at the regional level and to help identify or modify land use patterns that fit in with government policy objectives.

Weather Risk — Simulation models allow the interactions between timing of planting, fertilizer management, and season type to be investigated. The onset, distribution, and quantity of rainfall in Malawi exhibit such variability that optimal crop management practices vary from year to year, depending on the actual weather experienced. CERES-Maize was used to help define season types for a site in central Malawi. From historical weather data, season types were classified according to a simple set of criteria involving the ratio of actual-to-potential evapotranspiration. From these criteria, three equally likely season types were defined: seasons when the rains start early, normally, or late. There is a strong relationship between the date the rains begin for this site and the number of growing days during the season.

CERES-Maize was then used to simulate hybrid maize growth and yield for each season type. There is a marked change in mean yield as season type changes. It was still possible to obtain a high yield even with late planting, but it was much less probable than if the crop were sown earlier, due primarily to water stress occurring late in the season. The distribution of maize yields that occurs in any particular season can be derived once the start of the season is known. Thus, there are benefits to be gained from tailoring maize crop management to season type; in late-starting growing seasons, for example,

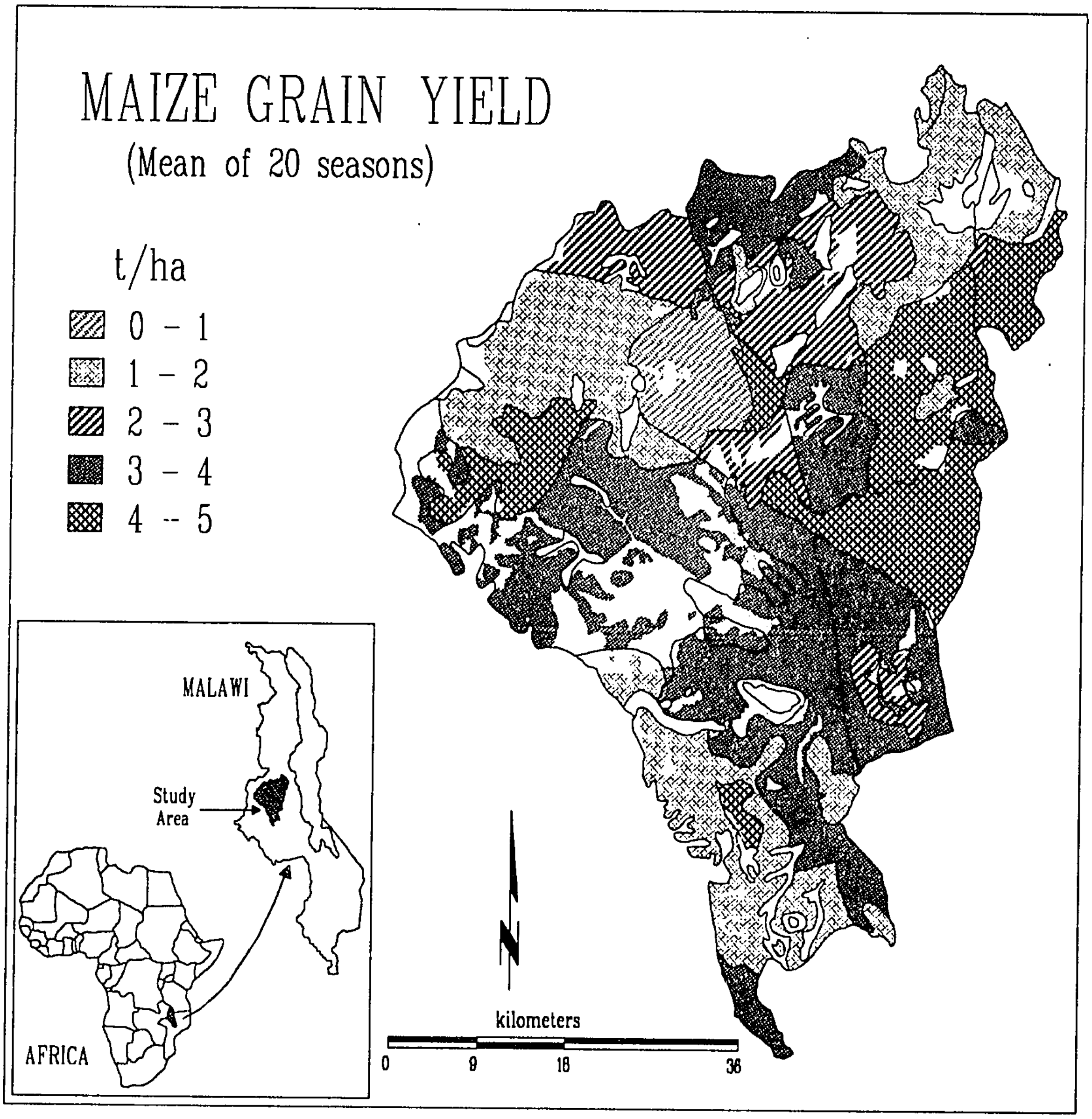


Figure 4. Simulated Mean Maize Grain Yield Replicated Over Twenty Seasons in Two Agroecological Zones in Kasungu Agricultural Development Division (MH-16 Planted December 14 With 30 kg N as Urea/ha Applied at Planting).

it may not be economical to apply much if any fertilizer. This type of analysis, although simple, could also be used to help select maize cultivars for a region based on the length of the growing season. Farmers could be advised, in a late-starting season, to grow short-duration maize cultivars or alternatively to grow other more drought-tolerant crops such as cassava.

Informal collaboration with the Malawi Department of Agricultural Research is continuing. In the coming months the model will be refined with more field data, and more model applications will be investigated for providing timely information to researchers and extension services.

Privatization of Farm Input Marketing Systems

Introduction

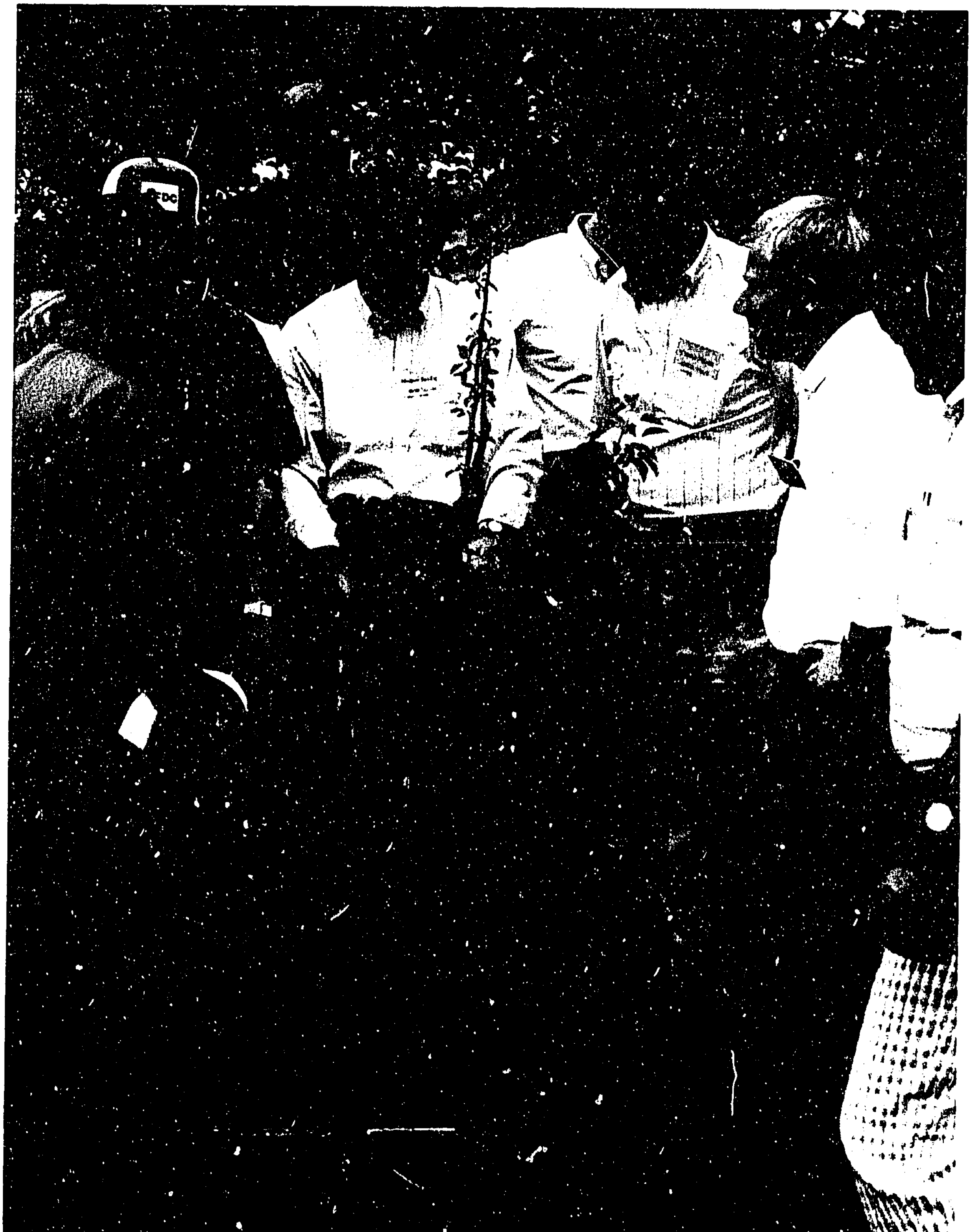
Countries that are involved in the transition from centrally planned economies to free market systems and developing countries that are transferring the ownership and management of state-owned enterprises to the private sector face a myriad of challenges. As these nations seek to raise their per capita incomes and foster economic development, their agriculture sectors play a vital role in the transition process. Many of these governments are turning to IFDC to receive the guidance they need to successfully institute the reforms required for privatization and to establish the institutions and infrastructure necessary to support open markets and distribution networks.

Policy reforms that create incentives for agricultural production and encourage international competitiveness of various farm inputs and commodities make agriculture a more cost-effective enterprise and increase its contribution to economic growth. These reforms should be carefully structured. Deregulation of crop markets and prices usually decreases the adverse impact of fertilizer subsidy removal on fertilizer use and agricultural productivity. In addition, policy measures affecting the prices of agricultural inputs and marketable products can increase the attractiveness of producing diversified farm commodities and accelerate production. If the policy reforms are incrementally applied across the entire agriculture sector over a period of time, a smoother transition usually results.

Open, competitive market systems must adhere to some basic principles, including freedom of entry and exit of supplies and products, an appropriate degree of competition, equal terms and conditions for all participants, economic pricing of supplies to allow for competitiveness on the international market, resource allocation based on market forces, and such regulation as is required to ensure consumer protection and safeguard national interests.

Privatization of agricultural markets requires the development of institutional capacity for a management information system to monitor and evaluate the results for each step in the reform process, a competitive distribution and farm production credit system, a legal framework for commercial private sector business, and strengthening of private sector capacities. During 1993 IFDC's agribusiness projects in Albania, Bangladesh, Egypt, Ethiopia, and Romania have provided a sound basis for the development of efficient agricultural input markets.

Training of fertilizer dealers is an essential component of IFDC's agribusiness program. With financial support from donors, IFDC cooperates with national and nongovernmental organizations to conduct this training. The Albanian dealers pictured here came to IFDC to enhance their understanding of the fertilizer products that they sell. In this photo they are visiting an Alabama (U.S.A.) fruit farm.



Highlights of 1993 Achievements

Albania

Since its initial venture into Albania in 1991, IFDC has implemented the first successful privatization project in that country. This project, which introduced the free market system in Albania, has created a strong, active dealer network that is linked with suppliers of other agricultural-sector inputs. IFDC has developed and implemented an effective marketing information system that is providing much needed information to the Albanian agriculture sector decisionmakers. To prepare them for a modern, free market economy, IFDC has trained Albanian bankers and dealers in marketing, credit, and financial planning. IFDC staff have introduced computer-based decision support systems to Albanian decisionmakers, researchers, extension advisers, and agribusiness leaders. To support agricultural production and marketing strategies, IFDC specialists have developed and implemented a viable resource information system. The IFDC Albania project has resulted in increasing credit disbursement by commercial banks to dealers based on need and credit worthiness. As a result of the project, an agricultural business newsletter is now being published by Albanians and distributed to dealers, extension agents, district agricultural officials, bank officers, government ministries, and research institutes. The fertilizer supply system has been integrated with world markets as evidenced by selling of diammonium phosphate and urea in Albania at near parity prices.

Albanian farm families are the ultimate beneficiaries of IFDC's work in that country.

During 1993 considerable progress was made in restructuring the fertilizer subsector. The number of private dealers has been expanded to more than 300, covering all districts of Albania. Fertilizer prices reached or exceeded world market parity levels while sales increased compared with those of 1992. Private dealers are expected to commercially import urea for the first time during the first quarter of 1994. Dealers have formed an association that is operating democratically, actively sponsoring business development activities, and convincing the government to provide a more enabling environment for farmers and dealers.

During 1993 commercial credit expanded greatly and mercantile credit was introduced which about equaled institutional credit. Progress has been made in improving the banks' credit disbursement procedures. Improving payment procedures has proven to be a slow process and major changes are still needed in the banking system in order to make needed improvements.

A scientifically sound statistical sampling system was established to permit the Ministry of Agriculture and Food (MOAF) to collect reliable agricultural data. Training was begun for data base management and report generation. Computer simulation was introduced to dealers, MOAF staff, researchers, and professors as a tool for improving decisionmaking.

Technical/economic evaluations were completed for both of Albania's domestic fertilizer factories. IFDC's recommendations for pricing and trade credit policies have generally been followed.

IFDC's project to privatize the Albanian fertilizer sector focuses on advancements in (1) private sector capabilities, (2) financial management, (3) management information systems, (4) commercialization of fertilizer factories, and (5) the formulation of production/importation strategies. IFDC's contributions in these areas during 1993 are discussed below.

Private Sector Capabilities — IFDC staff have increased the capabilities of private sector agricultural inputs wholesalers and retailers to market their products by establishing linkages between dealers and suppliers of other agricultural inputs. IFDC's dealer training has stressed that dealers need to strengthen their businesses by diversifying into other agricultural inputs. With this aim, IFDC collaborated with the Project Implementation and Coordination Unit, presently responsible for distributing EC PHARE seeds, agricultural equipment, and chemicals, in holding regionally based seminars to introduce these products to

IFDC is engaged in promoting fertilizer use in the main food crops in Albania. Pictured here is a demonstration plot on a farmer's field using mineral fertilizers and local farmers' crop management practices in a wheat-producing area of the country. Wheat, the principal crop of Albania, receives 27% of the mineral fertilizer consumed in that country. During 1993 wheat production reached 46.5 million tonnes and averaged 3,000 kg/ha.

fertilizer dealers. With IFDC assistance, the Albanian Fertilizer and Agricultural Inputs Dealers Association (AFADA) was registered with the Government of Albania during 1993. Probably the first of its kind in Eastern Europe, the dealers association members received training conducted by IFDC on dealer association organization and management. Several seminars on business financial planning were conducted for fertilizer dealers, bankers, and district agricultural officers. In addition, IFDC staff assisted Albanians with the publication of an agricultural business newsletter. IFDC marketing personnel used the mass media to disseminate information on fertilizer use, advertisements of seminars and meetings, and other important information.

Financial Management — The capabilities of bankers, fertilizer factory managers, and dealers in financial management have been improved. Bankers issued more short-term credit and have gained experience in the process. Factory managers initiated mercantile credit, and IFDC assisted fertilizer factory personnel in developing a system for tracing and accounting for payments. IFDC conducted regional workshops on the development of management skills and the improvement of payment procedures through the banking system.

Management Information Systems — During 1993 IFDC developed a Management Information System for Albania. This system is supporting project activities and will contribute to the future development of a national agricultural statistical service that is based on contemporary technologies. When fully operational, the national agricultural statistical service will contribute to increased agricultural productivity in that country and help sustain the free market economy. To make more informed decisions regarding the future of Albanian agriculture, its policymakers must have access to a reliable national agricultural statistical service.

When fully operational, the national agricultural statistical service will contribute to increased agricultural productivity in Albania and help sustain the free market economy.

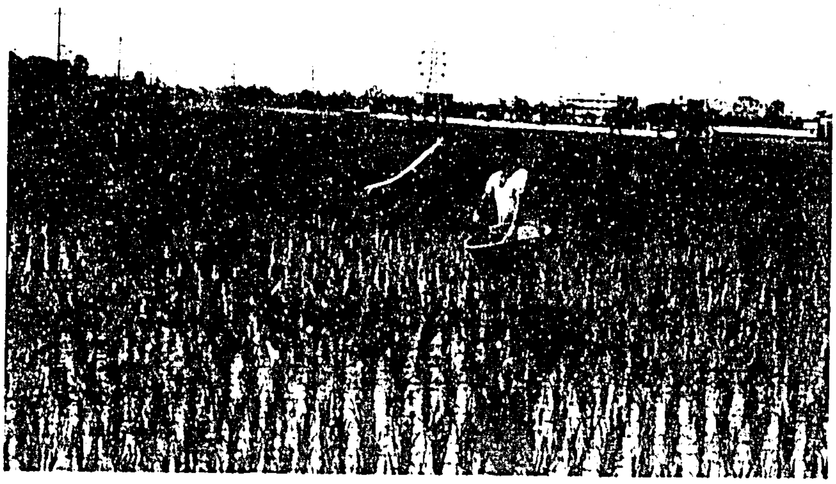
During 1993 an IFDC team traveled to Albania to design a system that will handle data from area sampling frame activities, to support an agricultural statistical system, and to initiate data collection needed for crop model/GIS work. In addition, the IFDC team conducted seminars to show how crop modeling-computer simulation linked with GIS can be used to provide information that helps people make better, more informed decisions. These seminars were attended by dealers, government decisionmakers, researchers, university professors, and students. The team also established two wheat field experiments to generate data to begin validation of the CERES wheat model in Albania, and weather stations were installed at the two locations. This technology can serve as a decisionmaking tool for fertilizer dealers in three to four regions. (For additional information on this part of the Albania project, please see the section of this annual report entitled "Management Information Systems for Sustainable Development.")

Commercialization of Fertilizer Factories — IFDC conducted seminars for fertilizer dealers at the Fier Nitrogen Fertilizer Factory to introduce new marketing techniques that were implemented to encourage dealer purchases. In attendance were fertilizer dealers, government officials, and officers of financial institutions. An important result of this IFDC involvement was the further creation of fertilizer dealers.

Production/Importation Strategies — The Fier Nitrogen Fertilizer Factory and the Lac Superphosphate Factory were evaluated to determine their technical/economic potential. Also, the potential for increasing the natural gas supply to the Fier factory was defined. IFDC staff held a number of meetings with groups of dealers to explain the realities of importing fertilizer. IFDC assisted the dealers in making the necessary financial, transportation, and legal arrangements for the first private import of urea into Albania that occurred in early 1994.

Bangladesh

In providing food for the growing population of Bangladesh, fertilizers have played a leading role and will continue to do so. The increased use of fertilizer and other inputs such as improved seed varieties and irrigation has made it possible for Bangladesh to achieve virtual self-sufficiency in rice production. Since 1987 Bangladesh has vigorously advocated and persistently pursued the privatization of fertilizer marketing. The task of developing further the new privatized market remains a continuing challenge for the Government.



As a result of the changes instituted during the Fertilizer Distribution Improvement Project II, fertilizer demand has increased by over 100% and the country has achieved self-sufficiency in rice production.

The removal of fertilizer subsidies and impact of privatization has resulted in the Government's realizing a combined saving estimated at US $43 million during 1992/93. Another advantage resulting from privatization has been the creation of an estimated 170,000 new jobs.

IFDC has been a key player in Bangladesh's becoming self-sufficient in rice production. With the implementation of the Fertilizer Distribution Improvement Project, initiated in 1979 with funding from USAID, IFDC has advised the Bangladesh Government on the privatization of fertilizer marketing. IFDC has facilitated the evolution of an extensive network of private entrepreneurs in Bangladesh, which has resulted in improved availability of fertilizers throughout the country. As a result of the changes instituted during the project, fertilizer demand has increased by more than 100% and the country has achieved self-sufficiency in rice production. These accomplishments were driven by the development of a highly competitive free market economy for fertilizer.

The Government's heavy subsidy burden caused by fertilizers has been eliminated, yet prices to farmers in real terms have declined. The removal of fertilizer subsidies and impact of privatization resulted in the Government's realizing a combined saving estimated at US $43 million during 1992/93. Another advantage resulting from privatization has been the creation of an estimated 170,000 new jobs. As a result of the IFDC Bangladesh project, 100% of the fertilizer imports are now handled by private traders. Many other benefits have been realized from privatization of fertilizer marketing and are discussed here.

Benefits to Farmers From Privatization of Fertilizer Marketing — The policy reform to establish an open, competitive fertilizer market has brought great benefits to farmers, particularly in terms of providing them easier access to fertilizers at reasonable prices. Effective competition at the wholesale and retail levels of fertilizer marketing promoted cost effectiveness and operational efficiency in the fertilizer delivery system, and farmers benefited by paying lower fertilizer prices.

The gross margin on fertilizer sales realized by fertilizer distributors did not increase significantly after subsidy withdrawal. The difference between the procurement price and the farm-level price of fertilizers from 1985/86 to 1988/89 is the difference between the prices at which dealers procured from the wholesale level and sold to farmers. On the other hand, the difference from 1988/89 onward is the difference between the procurement price at the distributor level and the farm-level prices. Thus, one would expect a large gap between these two prices after 1988/89, but efficiency and competition in the private sector maintained relative stability in the gap between the procurement price and the farm-level price.

After the private sector was allowed to procure directly from factories and import fertilizers, the availability of fertilizer, in general, has been satisfactory. Fertilizer sales are made by the private sector in all regional markets, and fertilizer availability in the local markets improved. Improved distribution and availability of fertilizer in rural Bangladesh are evident in the project's data, which show that about 80% of Bangladeshi farmers are now able to purchase fertilizers at retail shops within 5 km of their farms.

Employment Generation — Prior to 1978 the fertilizer market was completely controlled by the public sector, which was selling fertilizer from 460 thana centers. At that time, there were approximately 60,000 appointed retailers, of which only 6,000 were active. In 1989 a large fertilizer distribution network was established in the private sector. IFDC's recent estimates of those actively involved in fertilizer trade include 108,000 retailers, 13,000 wholesalers, 215 importers, and 1,400 distributors. In addition, these dealers employ about 60,000 persons. Total employment generated in fertilizer marketing, including the self-employed retail network, is estimated to be about 170,000 persons. If the average wage for these 170,000 persons is assumed to be US $1/day with a 200-day work year, this new employment generates about US $34 million/year in wages as a direct result of privatization.

Fertilizer Use and Rice Production — The public sector share of fertilizer marketing has decreased from 100% to less than 1%, and this has contributed to improved fertilizer use. Fertilizer sales increased from 731,000 tonnes of product in 1977/78 to 2,316,000 tonnes in 1992/93. The annual compound growth rate during this period was 8%. HYV rice accounted for about 70%-80% of the total fertilizer use. HYV rice production during the same period increased from 2,935,000 tonnes in 1977/78 to 12,035,000 tonnes in 1992/93 — a compound growth rate of 10%/year. Total rice production increased from 12,765,000 tonnes in 1977/78 to 18,340,000 tonnes in 1992/93. Several factors such as improved crop varieties, expanded irrigation, better cultivation practices, and increased and improved use of fertilizers contributed to the increase. Yield increases will continue to play an important role in meeting the growing demand for food and nonfood agricultural products in the future. Fertilizers will play a significant role in increasing crop yields because fertilizer use per hectare is still low in Bangladesh.

Fertilizer Cost and Return to HYV Paddy Production — Although the Government removed all fertilizer subsidies in 1992, competitiveness among fertilizer distributors and cost efficiencies achieved in the marketing network have moderated increases in farm-level prices. In the case of HYV paddy, the net return to farmers has remained virtually constant over the past 10 years. Net returns started increasing in 1984/85 and remained virtually constant until 1991/92. This increase is attributable to the increase in yield partly due to the increased use of fertilizer. During 1992/93 net returns decreased mainly due to a sharp decrease in output prices compared with those of 1991/92. Between 1991/92 and 1992/93 total cost increased by about US $50 (TK 2,000)/ha, and gross returns decreased by about US $92.50 (TK 3,700)/ha. Therefore, it is estimated that farmers earned a low but positive net income. However, this year (1993/94) with the increase in the paddy price, the net return increased considerably.

With the increased use of fertilizer nutrient per hectare from 45 kg to 113 kg, the share of fertilizer cost to total cost of HYV production increased from about 9% to 13% between 1980/81 and 1992/93.

Fertilizer Use in Diversified Crops — Although rice accounts for the major share of fertilizer, farmers are using fertilizer in other crops. In 1990/91 potato and wheat accounted for about 11% of total fertilizers used in the Rabi/Boro season. Fertilizer use on other crops is expected to increase as crop production is further diversified.

Savings to the Government From Subsidy Withdrawal and Privatization — Because the private sector now controls fertilizer marketing, the Government of Bangladesh no longer bears the expense of operating a state-controlled marketing system. Full-cost pricing of fertilizer and private fertilizer business activity have had a favorable impact on the national budget. Estimated combined savings to the Government of Bangladesh due to subsidy withdrawal and the impact of privatization was US $43 million in 1992/93. Allocation of these savings to other development work, especially in the agriculture sector, would create beneficial multiplier effects.

A Bright Future for Agriculture — Agriculture in Bangladesh has a bright future. Building upon the success achieved under the FDI-II project, the Government of Bangladesh and USAID have initiated the design of a new project that will focus on agrobased industries and technology development. The project will focus on achieving increased productive employment in agriculture and related enterprises, which is the key to achieving the poverty reduction goal of Bangladesh and USAID.

IFDC, as the prime contractor, in cooperation with Mississippi State University, Ronco International, and Winrock International Research Institute, was awarded the contract for the project design.

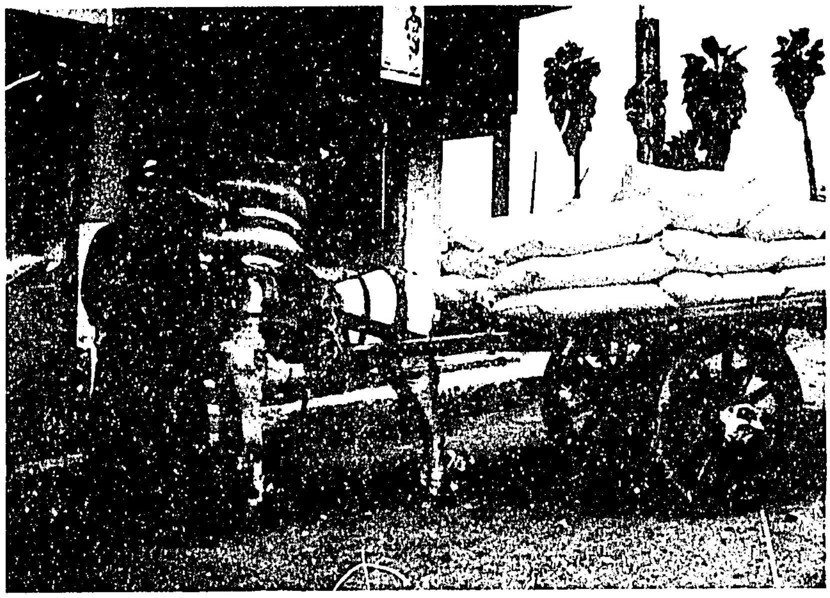
The new project, which is expected to begin in late 1994, will focus on five key subsectors: fertilizer, seed, poultry and livestock, agricultural machinery, and agricultural processing. Clearly the progress made in the fertilizer sector has provided the impetus for major progress in other agricultural sectors.

Egypt

In early 1993 IFDC conducted a study, sponsored by the Egyptian Ministry of Agriculture and Land Reclamation (through the Principal Bank for Development and Agricultural Credit [PBDAC]) and funded by USAID. The two major objectives of this study were to (1) make an assessment of the impact of the enacted policy changes on the farm sector, the fertilizer production companies, PBDAC, and the private sector and (2) identify and recommend further policy changes required for the continued development of an open, competitive market for fertilizers and pesticides.

In Egypt the production, procurement, and distribution of fertilizers functioned under the control of the Government of Egypt through two public sector monopoly organizations — one for production and the other for procurement and distribution. With a total cultivated and irrigated area of 2.4 million ha and a cropping intensity of 1.9 times per year, Egypt is a major consumer of fertilizers and has one of the highest annual rates of nutrient application per cultivated hectare at 315 kg. Total fertilizer use peaked in 1990/91 at 1,055,700 tonnes of nutrients.

Although fertilizer use increased significantly over the decade of the 1980s, agricultural output failed to improve substantially, an important



An Egyptian farmer collects fertilizer from a private sector fertilizer dealer in upper Egypt. Private sector dealers now account for 80% of all fertilizer marketed in Egypt, an accomplishment achieved since July 1991 when the market was liberalized.

contributing element to the country's overall unsatisfactory rate of economic growth. Recognizing that increases in agricultural output, including exports, were prerequisites for national economic growth, in the mid-1980s the government introduced a broad-based program directed at the progressive deregulation of the domestic economy. This program included the market-based pricing of production, the reform of public sector enterprises, and privatization. In keeping with the intent of the reforms, beginning in 1988 fertilizer prices were successively increased and subsidies eliminated in 1991.

Farm Level Impacts — IFDC's analyses of the impact of the policy reforms on crop and input prices indicated clear improvements in production technology and profitability for key crops, except cotton, and a substantial decline in the real (deflated) prices for all fertilizer products and all nutrients, despite sharp increases in nominal prices due to full subsidy elimination in 1990/91. The real overall nutrient price after policy reform was over 41% lower than in 1984/85, prior to the reform period. In addition, aggregate average fertilizer use was about 31% higher during the reform period.

The crop production analyses indicated a major shift to wheat during the reform period. Its increased area, yields, and total production clearly demonstrated that farmers responded strongly to the incentives created by the reforms. Similar responses occurred with maize and rice. In addition, net farm income per feddan (0.41 ha) from the major crops was, on average, 68% higher in real terms during the reform period.

Impact on Fertilizer Supply — Three reforms directly affected production costs and ex-factory pricing, namely: (1) removal of direct factory subsidy payments in December 1988, (2) increased energy costs closer to market prices in 1989, and (3) autonomy of setting ex-factory prices from July 1991. When direct production subsidies were removed, administered ex-factory prices were increased by between 142% and 301%. In spite of these increases, all the phosphate factories and some of the less efficient nitrogen factories were unable to cover full production costs. In 1989/90 phosphate ex-factory prices were increased between 32% and 50%, enabling profitable production.

Impact on Fertilizer Marketing — Following the reforms in 1991, the private sector reacted swiftly and with the cooperative sector accounted for 22% and 20%, respectively, of all factory liftings in 1991/92. During the first 6 months of 1992/93, the private sector share increased to 77% while the cooperative share remained at about 20%. The development of dealers (wholesalers/retailers) was equally rapid despite stringent licensing regulations.

Impact on Government Agencies and Cooperatives — The disengagement of PBDAC from fertilizer and other farm input distribution had a major impact on that organization, including the loss of income, the creation of redundant personnel, underutilization of storage facilities, changes in farm credit administration and control, and the loss of information concerning farm input use.

Highlights of Successes and Failures From the Reforms — The policy reforms that were enacted quite definitely removed distortions in resource allocation and alleviated imposed cost burdens on the farm sector to which farmers quickly responded. The deregulation of fertilizer distribution and pricing and the early disengagement of the public sector distribution agency resulted in a rapid transition to a competitive, efficient private sector role.

Failure by the production companies to fully adhere to agricultural pricing policy objectives led to some serious production problems and successful lobbying for differential tariff protection in 1993, which resulted in increased cost transfers to the farm sector. Inappropriate ex-factory pricing policies led to a concentration of fertilizer distribution within a few private sector companies and endangered competition. Inappropriate fertilizer dealer licensing regulations restricted legal market participation and competition.

Attention to these constraints in Egypt will ensure a continued smooth transition in the reform process and increased market efficiency.

Ethiopia

Ethiopia was faced with seemingly impossible conditions in 1991 after the civil war. The absolute priority was to increase food security through economic and market reforms to stimulate fertilizer use and agricultural production. Although the necessary overall economic policy reforms created substantial nominal fertilizer cost increases, particularly in 1992/93, fertilizer cost:benefit ratios were maintained at levels sufficient to stimulate fertilizer use. In part, liberalized grain marketing, which had been introduced prior to liberalization of the fertilizer sector, created a relatively efficient output market which protected farmers in the grain surplus regions from the fertilizer cost increases. However, in the low fertilizer use regions of the country where subsistence farming is the norm, the reforms have done little to stimulate fertilizer use, and the critical need for farm production credit remains a substantial constraint.

USAID introduced in 1992 an aid program aimed at supporting policy reforms targeted at increasing Ethiopia's agricultural sector productivity through the development of competitive private marketing systems with the specific objectives of private sector participation in the fertilizer and transport sectors. In 1993 IFDC was contracted by USAID/Ethiopia to conduct a study to assess the impact of policies implemented by the transitional government of Ethiopia on the development of competitive market systems in the fertilizer and related transport sectors.

The need to stimulate the economy through increased agricultural productivity was the main concern of the transitional government and the international finance and donor agencies in order to rapidly assist in reconstruction and rehabilitation. The pivotal role of fertilizer use in increasing grain production was recognized, and it was estimated by the World Bank that fertilizer use needed to increase by 20% per year just to maintain annual grain imports at current levels.

The IFDC study team spent 2 months in Ethiopia interviewing government officials, donor representatives, private sector entrepreneurs and

IFDC Senior Marketing Specialist/Financial Analyst, Ian Gregory, meets with Ethiopian farmers during the USAID-sponsored assessment of the privatization of that country's fertilizer and transport sectors.

fertilizer dealers, service cooperative personnel, and farmers. A preliminary analysis was conducted of the impacts of the reforms on the fertilizer and transport sectors. The key characteristics of Ethiopia's agricultural sector follow:

The Role of Agriculture — Ethiopia is a food deficit country with a rapidly growing population of about 50 million currently requiring food grain aid imports of almost 1 million tonnes per year. The agricultural sector plays a dominant role in the economy; it accounts for 47% of gross domestic product and 85% of exports and employs 85% of the labor force.

Cereal crops amount to 85% of the major cropped area and pulses, 11%. The main cereal crops are teff, barley, wheat, and maize. In good rainfall years about 6 million tonnes of cereals is produced. Average yields are low, 1.2 tonnes/ha for the major cereal crops in 1991/92.

Fertilizer Supply and Use — Ethiopia is totally dependent on imported fertilizers. Maximum fertilizer use occurred in 1991/92 at 100,000 tonnes of nutrients, when using an average of only 8 kg/ha for crops and pasture. About 94% of the fertilizer consumed is applied to cereals; maize and coffee are reported to be essentially unfertilized.

Impact of Policy Reforms — The economic policy and fertilizer market reforms were expected to stimulate competitive private sector participation in fertilizer procurement, distribution, and marketing with a subsequent increase in operational and economic efficiencies. Removal of price controls was expected to improve resource allocation and availability of fertilizers to small farmers.

In 1991/92 the private sector accounted for approximately 5% of fertilizer wholesaling and retailing. In 1992/93 this proportion increased to about 13% of wholesaling and 67% of retailing, and the private sector accounted for 13% of fertilizer imports.

New Marketing System — During 1990/91 and 1991/92 a considerable number of service cooperatives, which had been the only retail outlets for fertilizer, were destroyed or damaged as a result of hostilities and civil unrest. Following this loss of retail outlets, a new marketing system was established in 1991/92, whereby farmers could purchase fertilizer directly from marketing centers operated by the Ministry of Agriculture or by private sector dealers.

Substantial private sector participation in fertilizer marketing had thus been achieved within 2 years and had been considerably boosted by the USAID allocation of funds to the private sector; however, many restrictions to the development of a competitive market still existed.

Farm-Level Impacts — The most obvious change in fertilizer use during the reform period was the decline in use by the State Farm sector with an overall decline of 49% in nutrient use. The peasant sector increased on average by 25% for nitrogen and 32% for phosphate.

Romania

Once considered the bread basket of Europe, the East European country of Romania has 22.8 million people and 9.3 million ha of arable land. Eighty percent of this land is being returned to private land owners with a maximum limit

Reflections of the past...a look to the future of Romanian agriculture.

of 10 ha per owner. Traditionally a large producer and consumer of pork, Romania at the end of 1992 had a swine and poultry population of 9,852,000 and 87,528,000 head, respectively. While 55% of the swine and 53% of the poultry production is in private hands, both the feed milling and the slaughter industries continue to be state owned. Many encouraging signs point to a resourceful country that will cope with the transition from a centrally planned economy to a free market system.

At the beginning of this transition period, the Romanian farmers did not have an adequate delivery system to supply them with fertilizer, animal feeds, seeds, and other production inputs. The purpose of the involvement of IFDC in Romania was to help solve part of this problem. With funding from USAID, IFDC in 1992 began a US $8.5 million commodity importation program of high protein feed supplement targeted for the emerging and fragile private swine and poultry producers of Romania. Two objectives of this program were to introduce private swine and poultry farmers to a free market environment and to provide them with quality feed formulated to meet the specific needs of their swine and poultry.

The IFDC program was developed and implemented in two stages. During the first stage nearly 10,500 tonnes of protein-vitamin-mineral balanced feed supplement was imported in reusable 25-kg reinforced paper bags from the United States to the modern Black Sea Romanian port of Constanta. The feed supplement was formulated to give both the small and large farmer the needed flexibility to prepare finished feeds (rations) for each category of swine. Prior to the arrival of the cargo, nine regional seminars were held throughout Romania to explain the overall program; the criteria for participating in the upcoming eight regional, sealed-bid auctions at which the supplement could be purchased; and the date, time and location of the auctions. Information was provided on the proper use; cost:benefits of the supplement were expressed mainly in increased efficiency of feed conversion expressed in kilograms of feed per kilogram of live weight gained.

The culmination of the free market experience was realized through the multiple sealed-bid auctions held in 1993 at various locations throughout Romania. To many of the auction winners, IFDC provided monthly technical assistance and monitored the use of supplement over a 6-month cycle starting with the arrival of the feed supplement at the respective farms. Soon the feed intake to produce 1 kg of pork declined from 7.5 kg to 4 kg; use of the high-protein feed supplement also resulted in a decline in mortality rates and shorter fattening periods.

A second shipment was made and sold under circumstances similar to those discussed above. Of the 6,500 tonnes of feed supplement contained in the second shipment, which also arrived in Constanta in 1993, 2,500 tonnes was formulated as a universal feed for broilers and layers depending on the specific formula of the finished feed ration. The remaining 4,000 tonnes was formulated for swine.

The poultry feed supplement in general improved egg production, but its impact was most noticeable on broilers. The feed intake required to produce 1 kg of broiler weight gain declined from 3.1 kg to 2.2 kg. Consequently, the daily gain improved substantially and broilers could be delivered to the market in less than 55 days as compared with a previous lowest time requirement of 70 days.

A portion of the swine supplement was used for a pilot project to develop a dealer of agri-inputs to serve the small farmer's needs. The dealer chosen was ProdCo Impex SRL, Afumati near Bucharest. As part of this pilot project, two series of seminars were held with family-type farmers to explain the cost and benefit of the supplement, which could be purchased on a bag-by-bag basis. IFDC established a demonstration and a technical assistance program; soon the demand for the supplement outstripped the supply. As a result of this successful experience, ProdCo Impex SRL is also experimenting with the marketing of seeds and plans to supply fertilizer inputs to the small farmer.

As part of the USAID-funded project, IFDC continues to

The face of history . . .

In conclusion, the private swine and poultry growers of Romania enthusiastically embraced this program that gave them their first exposure to free market principles. Likewise, they were able to purchase quality feed supplements and with technical assistance from IFDC use it to prepare specific finished feed rations for their swine and poultry. Finally, an expected initial skepticism about the IFDC program in Romania has been transformed into a solid relationship between producers and IFDC based on trust and mutual respect and demand for more high-quality feed supplement. The project, which is funded through 1994, will continue to assist the Government of Romania and the private sector in developing ways to overcome the constraints to market liberalization. The most important constraints are the lack of production credit, insufficient foreign exchange to facilitate international trade, and domestic markets that do not offer reasonable returns.

the face of the future in Romania.

provide technical advice to the newly formed association of animal growers of Romania. The association was formed as a direct result of the IFDC program in Romania. In addition, IFDC plans to provide training in marketing and financial management to many of those who purchased swine and poultry supplement and to help establish a network of private dealers of agri-inputs that are essential in a market economy.

Another important component of the IFDC program was an assessment of the environmental and economic issues facing the swine and poultry producers with respect to the management of animal waste (manure). According to the IFDC study an estimated total of 13 million tonnes of swine and poultry manure is produced annually. IFDC continues to seek environmentally sound methods for the cost-effective management of this large amount of waste.

IFDC's Research to Address Environmental Issues

Introduction

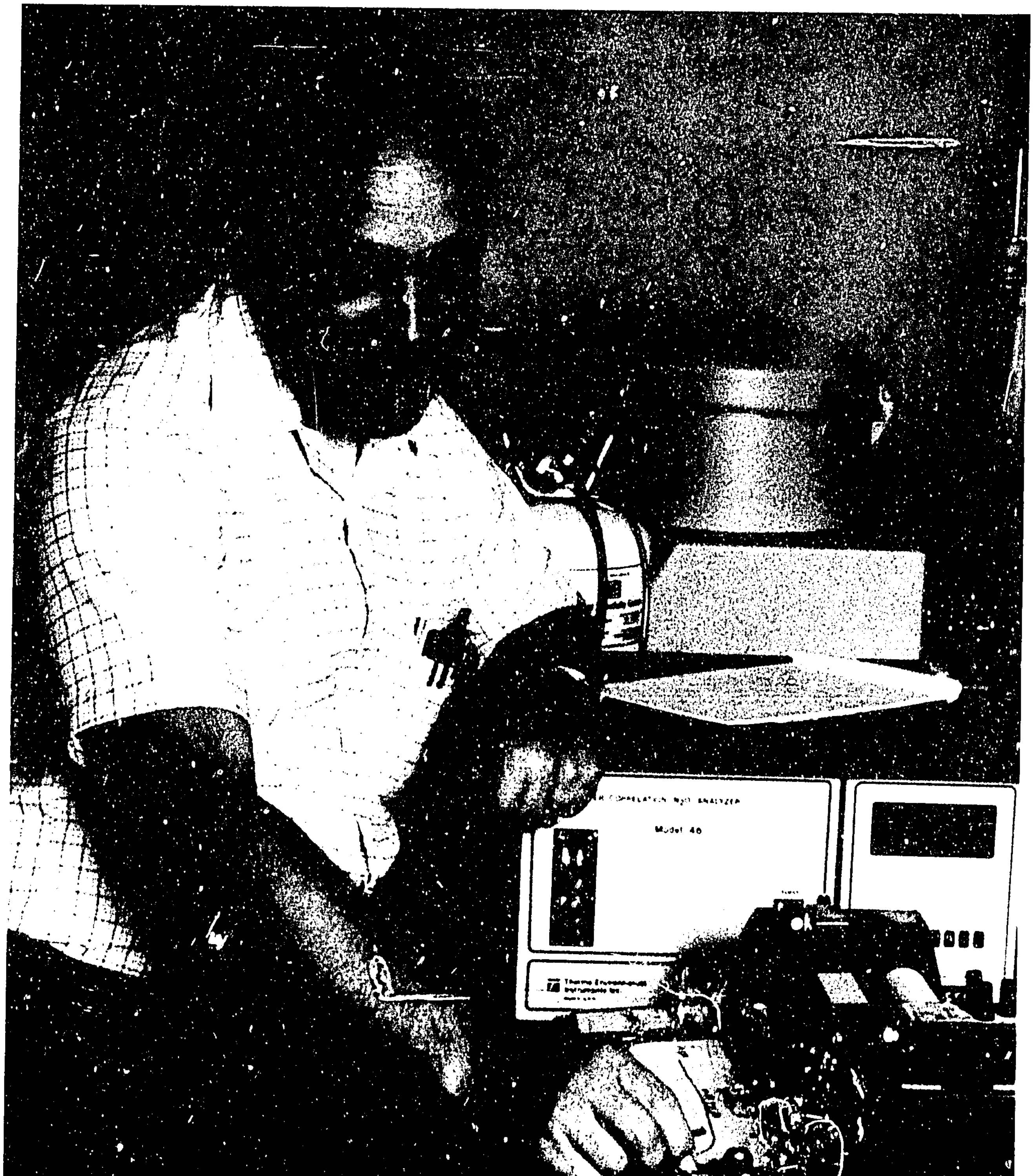
IFDC focuses on the promotion of proper plant nutrient use to create greater food productivity. This must be done in a sustainable manner so that the needs of today's generation are met without degrading natural resources and jeopardizing the ability of future generations to provide themselves with food and a higher quality of life. IFDC's goal is to develop and promote improved nutrient management practices related to each ecosystem.

Sustainability begins with the full use of locally available nutrients, including animal manures, agroindustrial wastes, and crop rotations. This involves better soil management practices and use of nitrogen-fixing plants, which will improve soil fertility and protect soils from degradation through erosion and organic-matter depletion. Soil fertility cannot be maintained over the long term by these sources alone because each harvest represents a net removal of nutrients from the land; thus, nutrients must be added to the soils. These are normally most economically supplied by commercial fertilizers. But a careful balance must be maintained since too many nutrients from whatever source wastes resources and pollutes water sources. Managing soils and nutrients to both increase productivity and avoid damage to the environment is central to IFDC's agenda.

An important aspect of IFDC's work that exemplifies its concern for environmental issues is its research on the fate of cadmium from nutrients to plants in tropical agro-ecosystems. Similarly, IFDC and IRRI are jointly assessing the impact of fertilizer application on the emission of methane and other greenhouse gases from paddy fields in Asia. The findings in these areas of research are discussed in the section that follows.

Environmental Research

Dr. E. Rick Austin, Coordinator of Analytical Services, conducts experiments to measure emissions of nitrous and nitric oxide from flooded rice systems. IFDC has developed research methods that can be used in field measurements to be undertaken in the Philippines as part of the IRRI/IFDC Collaborative Program.



Highlights of 1993 Achievements

Greenhouse Gas Emissions From Flooded Rice Systems

Methane Emission Research — Flooded rice soils are estimated to produce about 25% of the total methane emissions to the atmosphere. It is produced from anaerobic fermentation of organic materials by soil bacteria when the soils become highly anaerobic. Methane is believed to be an important "greenhouse gas," which absorbs infrared radiation and causes heating of the earth's atmosphere. While there are many research projects that are measuring methane emissions from flooded rice fields, there is a lack of basic understanding of the sources of carbon for emission and factors that affect emissions of the gas. IFDC scientists are attempting to provide basic information on the phenomena that will aid in understanding the mechanisms of methane production and emission. This information is needed to develop models for methane emission and possible methods of reducing emissions.

Ronnie Faires, Senior Greenhouse Technician, prepares equipment to determine methane emissions from flooded rice soils.

The rice plants serve an important role in methane emissions by acting as conduits for movement of the gas; it has been estimated that 90% of the methane is emitted through the plants. Using a split chamber system that allows measurement of methane emitted through the plants and directly from the soil, IFDC scientists found that bubble evolution of the gas from the soil is frequently an important source of methane. Plant-mediated emissions were found to be very constant over day and night periods, but direct soil emissions increased to account for over 60% of the total emissions when methane production rates were particularly high. Soil emissions were frequently very high during the day and decreased during the night, for an as yet unknown reason.

Under controlled temperature conditions (32°C) plant emissions were constant over day and night periods although this rate changed during the seasons. When the soil was allowed to dry at harvest, gas emissions both through the plants and directly from the soil greatly increased until the methane entrapped in the soil was largely emitted. This phenomena is thought to be caused by the partial drying of soil pores, which allowed more rapid movement of the gas to plant roots for transport or gas movement through the soil pores to the surface.

Research will continue to examine the basic relationships of methane production and emission from flooded rice systems to facilitate the development of process models that will provide better estimates of emission and identify possible methods of reducing methane emissions.

Nitrogen Oxide Emissions From Rice Systems — Two fertilizer-related nitrogen gases that are emitted from soils are of concern as atmospheric contaminants. Nitrous oxide is a "greenhouse gas" similar to methane in that it absorbs light radiation in the atmosphere and possibly accounts for 5% of the total contribution to atmospheric warming. Nitric oxide is another soil-emitted gas, which is a major pollutant in industrial areas, and reacts with natural cleansing agents in the atmosphere. Research has been conducted at IFDC and IRRI to measure the emission of these two gases from the flooded rice system, particularly during dry-season fallows when the soil is rewetted and approaches saturation from monsoonal rains.

During the dry season, when rice cannot be grown because of water limitations, high amounts of nitrate are formed by nitrification, which can produce both nitrous and nitric oxide. When the wet season begins and soils become more anaerobic, nitrous oxide emissions can increase since this gas is also produced from denitrification. With the assistance of scientists of the Atmospheric Science Division of the Tennessee Valley Authority's Environmental Research Center, research was conducted to determine the effect of nitrogen fertilizer application to the previous flooded rice crop and the relationship of the emission of the two gases to soil water and rainfall events.

The patterns of nitric oxide emissions changed as the soil became wetted. During the actual dry season, nitric oxide emissions were quite high and were the highest immediately following a simulated rainfall event. During this period, nitrogen fertilization of the previous crop had no effect. As the soil was wetted at the beginning of the simulated rainy season, the nitric oxide emissions decreased, but there was an increased amount of this gas emitted from the fertilized treatments. The emissions of nitric oxide decreased as the soils approached saturation and increased as the soils dried after the rainfall events. The total emissions of nitric oxide were about 0.9 kg nitrogen/ha.

The emissions of nitrous oxide were very small during the dry season and did not become appreciable until the onset of the simulated rainy season. The nitrous oxide emissions were not affected by nitrogenous fertilizers, and they occurred about 2 days after the rainfall events. Total emissions of nitrous oxide amounted to approximately 1.2 kg nitrogen/ha.

This research demonstrates the strong relationship of nitric and nitrous oxide emissions to rainfall events and soil moisture. The results will aid in developing models and help identify methods of reducing emissions of these gases. It has helped to develop research methods that are now being used in field measurements in the Philippines as part of the IRRI/IFDC Collaborative Program.

Economically significant losses of nitrogen due to denitrification have not been reported from flooded rice fields. However, past IFDC-IRRI collaborative studies have shown appreciable buildup of soil nitrate (52-77 kg NO_3-N/ha) during fallow periods. All of the nitrate accumulated in the dry season fallow is lost through denitrification losses immediately after permanent flooding. Besides the economic losses the denitrification product, nitrous oxide, is a very potent greenhouse gas (300 times more radiatively active than carbon dioxide on a mass basis). It also contributes to the destruction of stratospheric ozone.

Field studies conducted by the IFDC-IRRI project during the 1993 dry-wet transition period showed fluxes of nitrous oxide between 25-70 g nitrogen/day upon flooding after a 6-8 week fallow period. High fluxes of nitrous oxide (30-100 mg N_2O-N/m^2/day) have been measured immediately following rainfalls exceeding 2 cm during fallow periods. The formation and emission of nitrous oxide is apparently due to denitrification of accumulated soil nitrate. Nitrous oxide was also produced from nitrification of ammonium in the dry surface layer and denitrification in the wet subsoil between rainfall events in the fallow period. Nitrous oxide emissions during these times (1-2 mg N_2O-N/m^2/day) were about 10 times higher than during the flooded rice season.

Management of the fallow period to cycle native soil nitrogen into post-rice crops or weeds will reduce soil nitrate accumulation and reduce fluxes of nitrous oxide; however, it may stimulate methane production and emission on flooding.

Impact of Phosphorus Fertilizer Use on Cadmium in Soils and Plants

All phosphate rocks and phosphate fertilizers produced from them contain cadmium, some more than others. If ingested by human beings or animals, cadmium is highly toxic. When phosphate fertilizers containing cadmium are applied to the soil, the cadmium in the fertilizer is deposited in the soil. The impact of intensive and extensive use of phosphate fertilizers on cadmium in soils and its possible entry into the food chain through crop uptake in amounts that could be potentially hazardous to human and animal health continued to be a focus of research of IFDC scientists.

The earlier program of monitoring cadmium levels in soils in selected fields with a long fertilizer use history in different ecozones was continued in 1993. A one-time application of 18 tonnes/ha of local phosphate rock in Thailand had no significant effect on cadmium in soils or uptake by rice grown 6 years later. Total cadmium in soil, rice straw, and grain from fertilized plots was 600, 800, and 400 μg/kg compared with 700, 700, and 400 μg/kg, respectively, from samples collected from the unfertilized plots. Likewise, application of 5 tonnes/ha of phosphate rock over a period of 4 years did not result in any increase in cadmium content of soybean grains though there was an increase in the total cadmium content of soils.

Several experiments were conducted in the greenhouse to study the effect of quality and quantity of phosphate fertilizers applied, effect of soil properties, and other factors influencing uptake of cadmium by plants.

To investigate the effect of repeated, annual applications of small amounts of phosphate fertilizers containing different amounts of cadmium, a multiseasonal trial was set up in an acidic Ultisol (pH 4.8). Two phosphate fertilizers having relatively high amounts of cadmium (North Carolina phosphate rock, 47 mg cadmium/kg phosphate rock and Togo partially acidulated phosphate rock [PAPR], 40 mg cadmium/kg) were applied to the soil at 50 and 100 mg phosphorus/kg rates. Maize and upland rice were grown as indicator crops. At the end of the first year's study, there was no increase in total or extractable cadmium in soils from the application of different phosphorus sources. There was a difference in concentration of cadmium in maize and rice (Figure 5) tissues due to the rate and source of phosphorus applied, but the total cadmium uptake was not significantly influenced by the cadmium content of the phosphorus applied. The high tissue concentration of cadmium in the sample from the control treatment and comparatively low concentration in the sample with larger biomass is due to the dilution effect.

In another experiment the same phosphate fertilizers were applied to the same soil at very high rates, including 1,000 and 2,000 mg of phosphorus/kg to investigate the effectiveness of intensive application of phosphate fertilizers on cadmium uptake by plants. Two crops of maize were grown sequentially. At the end of cropping, the extractable cadmium in soils was < 0.02 mg/kg except in soils treated with Togo PAPR in which case extractable cadmium ranged from 0.04 to 0.13 mg/kg, depending on the rate of fertilizer used. At rates above 500 mg of phosphorus/kg, cadmium uptake by maize from different fertilizers was significant and followed the order of Togo PAPR > North Carolina phosphate rock > TSP > Morocco PAPR. Cadmium concentration in plant tissues decreased with increasing biomass production. The relative magnitude of cadmium in plant tissue and total phosphorus uptake depended on the amount, form, and solubility of phosphorus and level of cadmium in the fertilizer. A higher phosphorus availability improves plant growth that in turn increases cadmium uptake in plants.

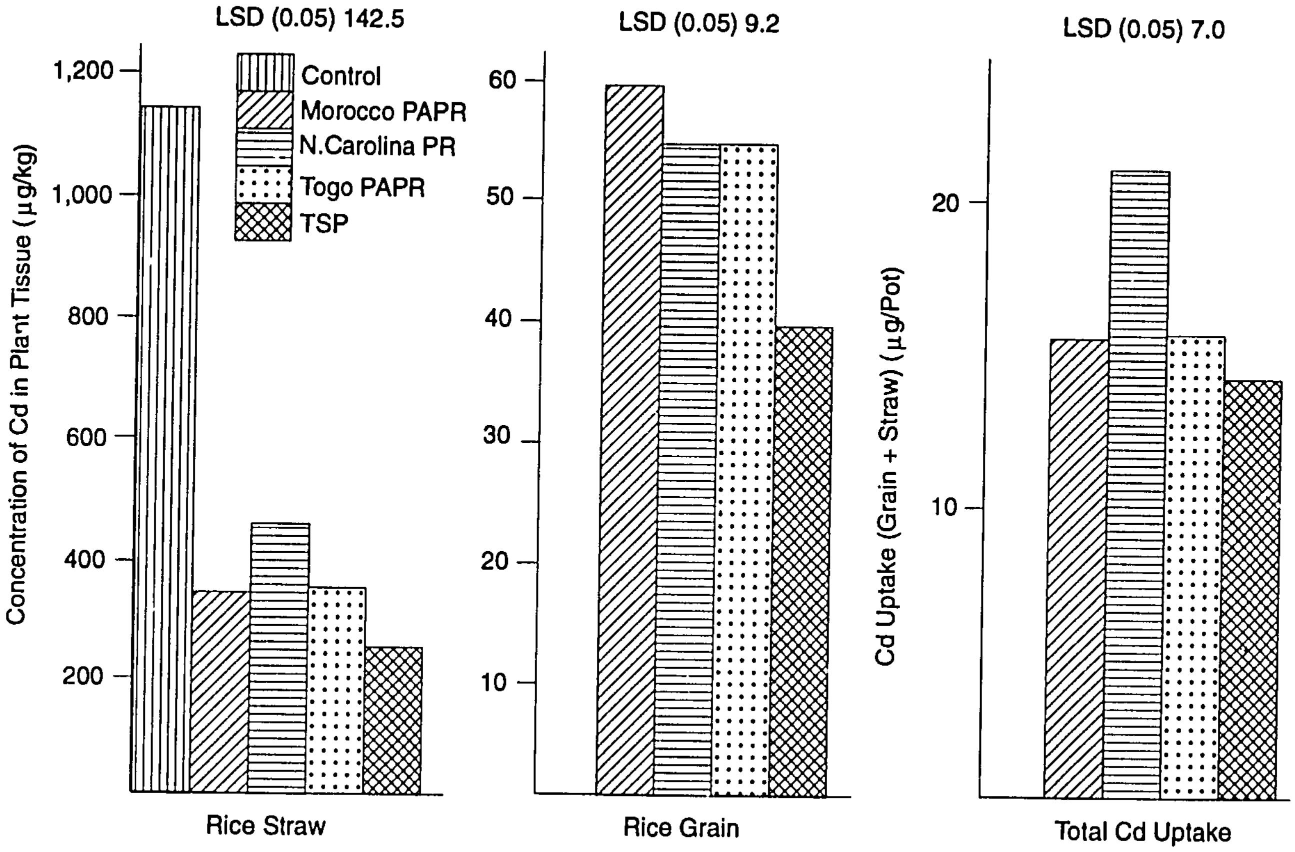


Figure 5. Cadmium Concentration in Plant and Uptake by Rice Fertilized With Phosphate Containing Different Amounts of Cadmium.

Management Information Systems for Sustainable Development

Introduction

Increases in productivity, preserving the environment, sustainable land use management, and liberalization of state controls are leading to the creation of dynamic agricultural systems in the developing countries. To perform efficiently, researchers, policymakers, and farmers must have access to sound techniques in decisionmaking, and information that is relevant, accurate, and timely. IFDC researchers are working in projects in countries in Eastern Europe, Asia, Africa, and Latin America in the implementation of information systems, decision support systems, and policy analysis supporting these agricultural development activities. In collaboration with other international agricultural research centers (IARCs) and IBSNAT, IFDC scientists develop dynamic models that simulate crop growth. This research focuses on crop and nutrient modeling and the application of crop models at diverse levels of integration with linkages to socioeconomic models, expert systems, and GIS. Activities include the refinement, testing, and documentation of crop growth simulation models and nitrogen and phosphorus dynamics models for food crops. Long-term impacts of particular management practices can thus be studied to assess the sustainability and stability of cropping systems. Collaborative model application projects are being implemented in countries of Asia, Africa, and Latin America. These crop models are valuable tools that can be used to assist decisionmakers in planning and evaluating agronomic practices and nutrient dynamics to create sustainable agricultural development.

Dr. Julio Henao, IFDC Senior Biometrics Scientist (left), discusses the development of Albania's national agricultural statistical system with Dr. Carlos A. Baanante, Director, IFDC Research and Development Division, and members of the Albanian Directorate of Information and Statistics — Servet Kalemi, Statistician; Mynevere Rusi, Chief of Agricultural Statistics; Shkelqim Agolli, Director of Statistics, Ministry of Agriculture and Food; Zana Curakuqi, Chief of Agroindustrial Statistics; and Ilirjan Bimo, Manager of Management Information Systems, IFDC-Albania.

Highlights of 1993 Achievements

An Area Sampling Frame for Albania

One objective of IFDC's privatization project in Albania (also see section entitled "Privatization of Farm Input Marketing Systems") is to help and support Albania's development of stable, viable agricultural production through establishing and institutionalizing agricultural information systems, to be managed by Albania's Ministry of Agriculture and Food.

During 1992 IFDC contracted with the Agricultural Assessment International Corporation (AAIC) to construct an area sampling frame (ASF) for agricultural survey purposes in Albania and to conduct the first area crop survey. The objective was to estimate crop areas and determine production of wheat. During 1993 the MOAF in collaboration with IFDC and AAIC undertook a second area survey to estimate agricultural land and fertilizer use, develop techniques to forecast wheat and maize production, and enhance the ASF technology through refinement of previous land stratification and sampling. The main goal was to provide an efficient technique that would improve future surveys and sampling strategies in the country.

The area frame and an associated computerized system were designed and implemented in a manner that will allow the sample unit of information to be digitally stored and will facilitate estimation of parameters and sample analysis. The system has been designed to support users' needs for agricultural statistics including cropped land, agricultural resources, and selected socioeconomic indicators. The system is uniquely adapted to Albania's conditions, needs, and resources.

The primary objectives of the area sampling frame design in Albania are to provide the basis for periodically estimating cropland areas for major crops, forecast the production of crops, and determine products and amounts of fertilizer applied during the cropping season. A long-term objective is to provide the basis for the establishment of a national agricultural statistical system for monitoring and reporting agricultural development.

For the design and construction of the area frame across the country, maps were needed as well as available reports on topographic features, crop production, crop and fertilizer management, fertilizer use, and intensity of land use in the country.

Sampling strategies based on reliable frames and probability sampling schemes will contribute to speeding the process in obtaining reliable estimates. Surveys based on area sample frame methodology represent an appropriate strategy for the establishment of a monitoring system to continuously evaluate agricultural productivity and facilitate policy decisions for projecting future developments of the Albanian agricultural sector.

This mountainous area of northern Albania in the Kukes region was included in the area sampling frame produced by IFDC. The primary crops of this region are wheat, alfalfa, and vegetables.

Interactive Crop Model-GIS: One Component of a Management Information System for Albania

In addition to its efforts in agricultural input dealer development and credit infrastructure support, IFDC is assisting Albania by introducing that country's policymakers to technology that is available to help them assemble the information needed to derive viable solutions to particular problems.

With support from USAID a team of IFDC scientists visited Albania in 1993 to demonstrate some of the modern information technology tools that are available and to show how such tools can be used to provide information that helps people make better decisions. Prior to their departure for Albania, the scientists assembled a prototype crop model-GIS at IFDC Headquarters. This prototype covered four of the most intensive agricultural regions of Albania — Lushnja, Fier, Korca, and Shkodra. Weather data for the four regions were assembled from a variety of sources. Maps of soil types were prepared, and corresponding soil profile characteristics for use with the crop models were estimated from profile descriptions provided by the Institute for Soil Studies in Tirana.

The prototype system can be used to produce soil and agroclimatic maps for the whole country, run the CERES-wheat crop simulation model for the four primary agricultural regions, and map sales regions for individual dealers so that demand projections can be made for their target markets.

The IFDC scientists made six presentations throughout Albania, which were attended by approximately 300 people. The following format was used in each presentation:

- An introduction to computer-based tools, such as the GIS and crop simulation models and how they can be used to assist in making decisions.
- A demonstration on how to run the wheat model and derive a nitrogen fertilizer response curve using the decision support system for agrotechnology transfer (DSSAT) software. Various costs and prices were then added to show the difference between the agronomic and the economic optimum using a graphical interface.
- Participants suggested different agronomic management options that were analyzed using the DSSAT.
- The crop model GIS system was then shown, and the fertilizer demand program was demonstrated.

A number of possible applications of the prototype model were illustrated. For example, Figure 6 shows the simulated nitrogen response curve for a wheat crop planted in Lushnja, Albania, on one soil type using historical weather data from the 1977/78 season. With a typical fertilizer cost of 60 lek/kg of nitrogen and a grain price of 18,000 lek/tonne of wheat, the economic optimum application of fertilizer in this season would be about 150 kg of nitrogen. If, however, the cost of urea were to double to 120 lek/kg while the price of grain remains the same, the economic optimum would be lowered to about 100 kg of nitrogen. Likewise, any number of similar cost-price relationships for different response curves can be easily examined.

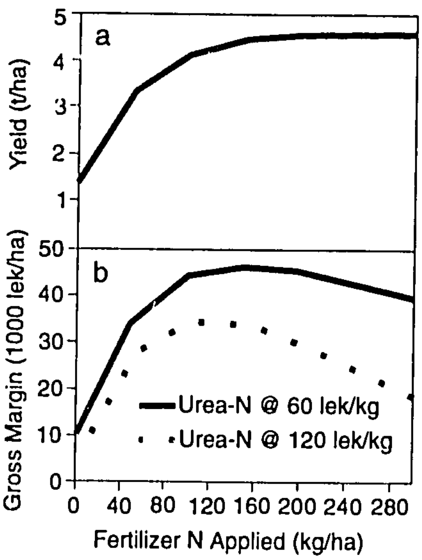


Figure 6. Simulated Nitrogen Response Curves for Wheat Grown at Lushnja in 1977/78.

The type of output obtained from linking the crop model to the GIS system is illustrated in Figures 7, 8, and 9. Figure 7 shows the location of the four pilot regions in Albania with the soils map enlarged for Lushnja. Figure 8 shows the expected soil type and the amount of nitrogen fertilizer applied. This output was obtained by running the wheat model for each soil type in

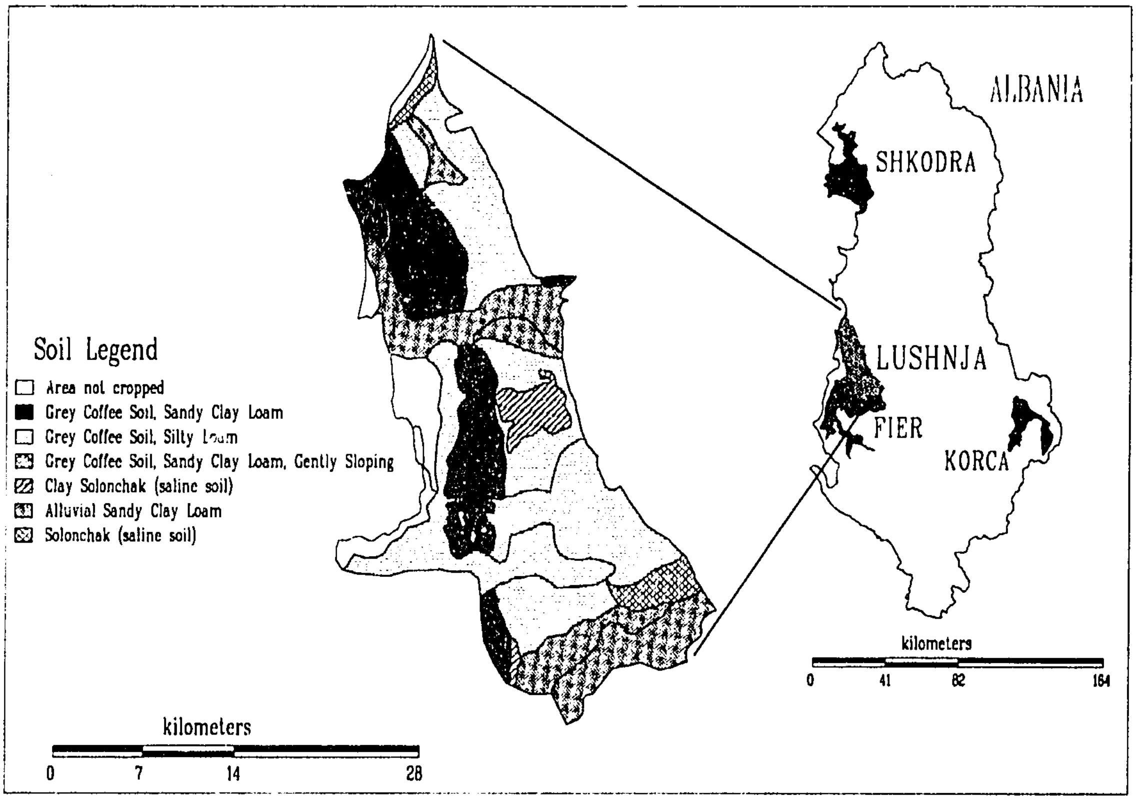


Figure 7. Location of Pilot Regions in Albania and the Soils Map for the Lushnja Region.

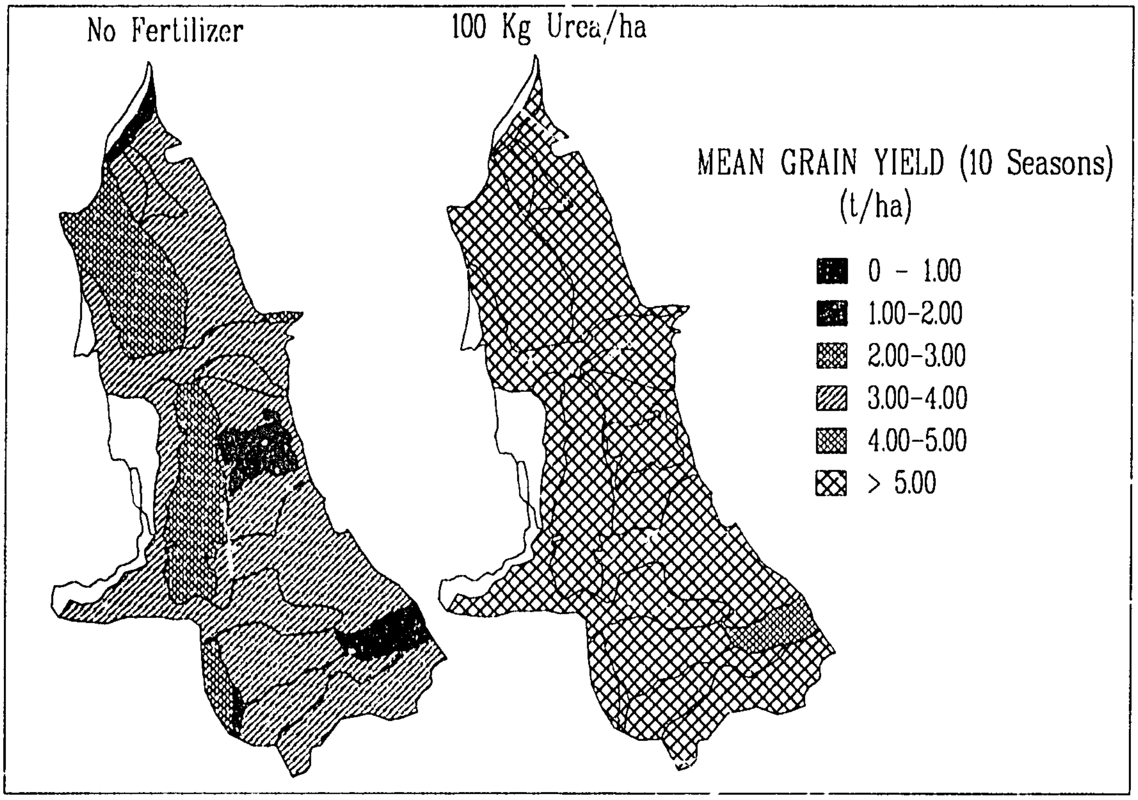


Figure 8. Average Simulated Wheat Yields in Lushnja With and Without Fertilizer Nitrogen.

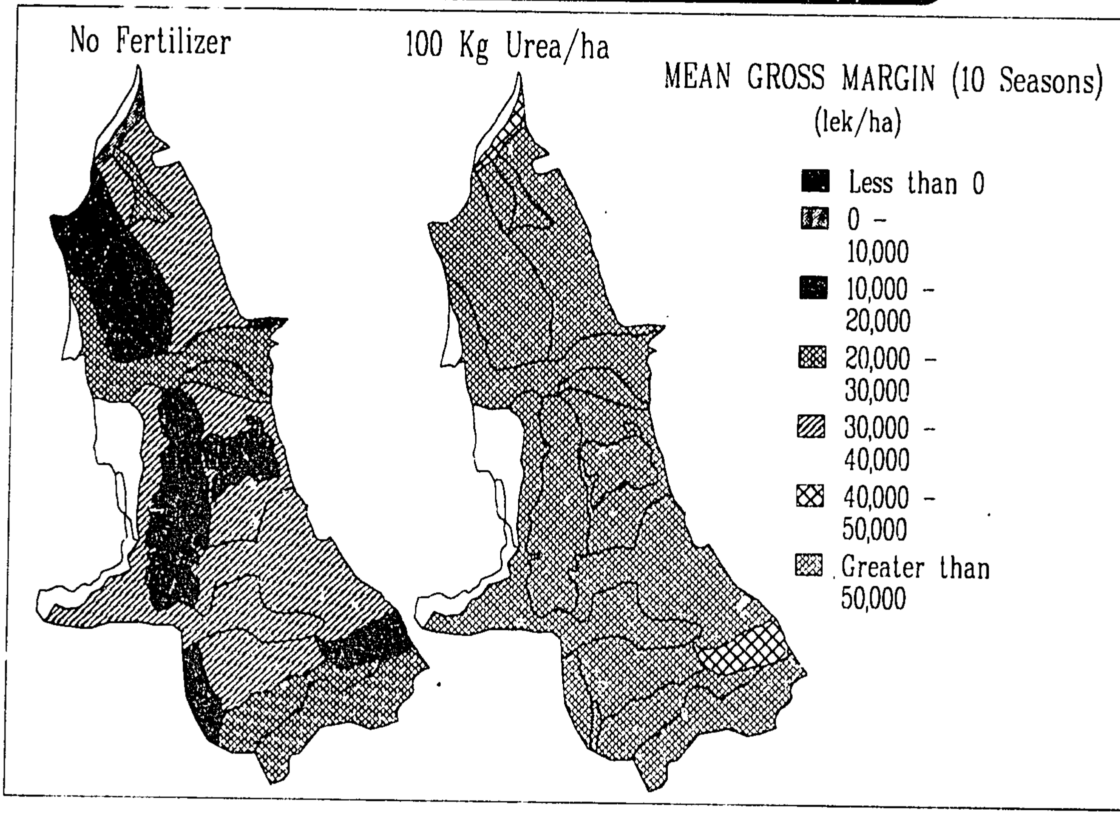


Figure 9. Average Simulated Gross Margin for Wheat in Lushnja With and Without Fertilizer Nitrogen.

Lushnja with 10 different weather years, first assuming no nitrogen fertilizer was applied, then assuming 100 kg of nitrogen/ha was applied as urea. Note that inherent differences in soil properties resulted in greater variability in yield when no nitrogen fertilizer was applied. Figure 9 shows how gross margins would vary for the simulated grain yields using typical fertilizer costs and grain prices. New maps can be drawn quickly for alternative management options and cost-price relationships. Such information can be used to assess regional production levels and to highlight the locations that are highly suitable for winter wheat production.

The prototype system can also be used to estimate the on-farm demand for nitrogen fertilizer, using assumptions that the user can easily change. This type of information can be used by the fertilizer dealer to estimate the peak demands for nitrogen fertilizer during the season so as to match supply and demand for fertilizer.

The prototype model-GIS will be further developed to give nationwide coverage. The Ministry of Agriculture is using an ASF method developed and introduced by IFDC that allows national estimates of cropped areas and yields to be estimated from a comparatively small sample of field plots. Production and socioeconomic data have been collected through surveys using the ASF and will continue to be collected in the future. The GIS will be linked to these data bases, allowing the data collected to be mapped and analyzed using the system.

Two field trials were planted at the University of Tirana and the Agricultural Research Institute in Lushnja; these trials are being run by Albanian scientists for validating CERES-wheat.

The formation of a multidisciplinary team of Albanians trained in the use of the crop models and GIS that could feed relevant and timely information to policymakers is a critical activity over the next few months. The situation in Albania offers a unique opportunity for attempting to do something radically different and innovative in terms of information provision for decisionmakers throughout the agricultural sector. The demonstrations were helpful in fostering support among Albanians for these activities, and the Albanians themselves are keen to develop the prototype to its full potential.

Watershed Management in West Africa

Introduction

The Watershed Management Program recognizes that sustainable crop production systems in West Africa can be developed through the conservation of water, soil organic matter, plant nutrients, and the physical attributes of the soil. An event resulting in land degradation in one corner of a watershed is often felt eventually throughout the entire watershed. Therefore, protection of the environment for sustainable crop production in a given watershed should be based on a knowledge of the climate, geology, soils, hydrology, vegetation, landscape, and the people in that watershed. The goal of the program, therefore, is to increase food security and reduce poverty in West Africa by developing and promoting technologies that increase productivity and combat desertification and land degradation. Funding for this work comes from the African Development Bank and the United Nations Development Programme (UNDP).

In cooperation with national and international institutions, IFDC-Africa is conducting agronomic research to find cropping systems that can halt or alleviate soil degradation and thus contribute to the development of sustainable agriculture in West Africa. One example of this type of system is the cultivation of legumes, which are natural "fertilizer factories." Legumes have nodules on their roots containing nitrogen-fixing bacteria capable of capturing nitrogen from the air to provide the crop and following crops with nitrogen. Funding for this work comes from the African Development Bank and UNDP. (Shown here is Agbo Kodjovi, a University of Benin student from Togo, who received training at IFDC-Africa as part of his M.S. degree program in agronomy.)

Highlights of 1993 Activities

Research to Improve Soil Fertility in the Sahel

Crop Rotation to Improve Efficiency of Phosphate Fertilizers — Phosphorus is the most important nutrient limiting crop production in the Sahel. Field trials were established in 1990 in Niger to study the effects of a rotation involving pearl millet and cowpea on phosphate use efficiency. The treatments were as follows: continuous millet, millet following a crop of cowpea, and an intercrop of cowpea and millet. The results showed that rotating millet with cowpea improved the yield of millet. Most importantly, the rotation improved the efficiency with which millet used applied phosphate fertilizers (Figure 10).

Use of Crop Residue to Improve Soil Productivity in the Sahel — Long-term field experiments were established in Sadore in the Sahelian zone and in Tara in the Sudano-Sahelian zone to study the effect of mineral fertilizers and crop residue application on soil productivity. For 10 years at Sadore, both fertilizers and crop residue applied alone greatly increased crop production. The highest yields, however, were obtained when crop residue was applied in combination with mineral fertilizers.

The situation in the more humid Sudano-Sahelian zone was entirely different. Except for 1990, the application of crop residue alone or in combination with mineral fertilizers has failed to increase millet yields. This is especially surprising since the rate of decomposition of millet straw in Tara is much higher than in Sadore.

At Sadore, the application of crop residue significantly increased the organic matter content of the soil and the soil's ability to retain plant nutrients. This improvement in soil properties can explain the improved performance of millet in this environment. At Tara, the addition of crop residue failed to raise the organic matter level.

At both sites, the use of mineral fertilizers alone decreased the base saturation, decreased soil pH, and increased aluminum saturation. Thus, even

A new study is in progress in the Sahelian and Sudano zones of West Africa to assess the seriousness of micronutrient deficiencies in the West African soils.

though the use of crop residue may not result in immediate increase in crop yield, it is advisable that a combination of crop residue and mineral fertilizers be used in most soils of West Africa. The behavior of

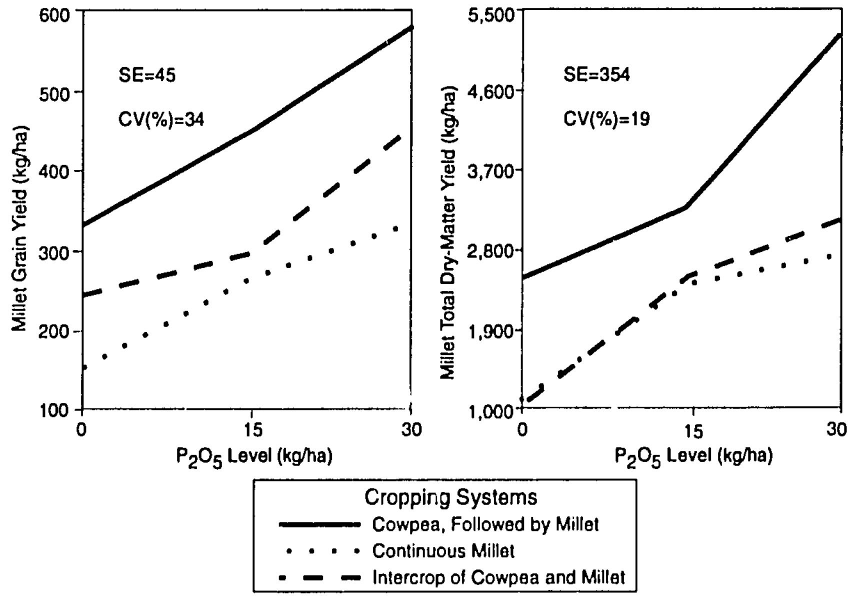
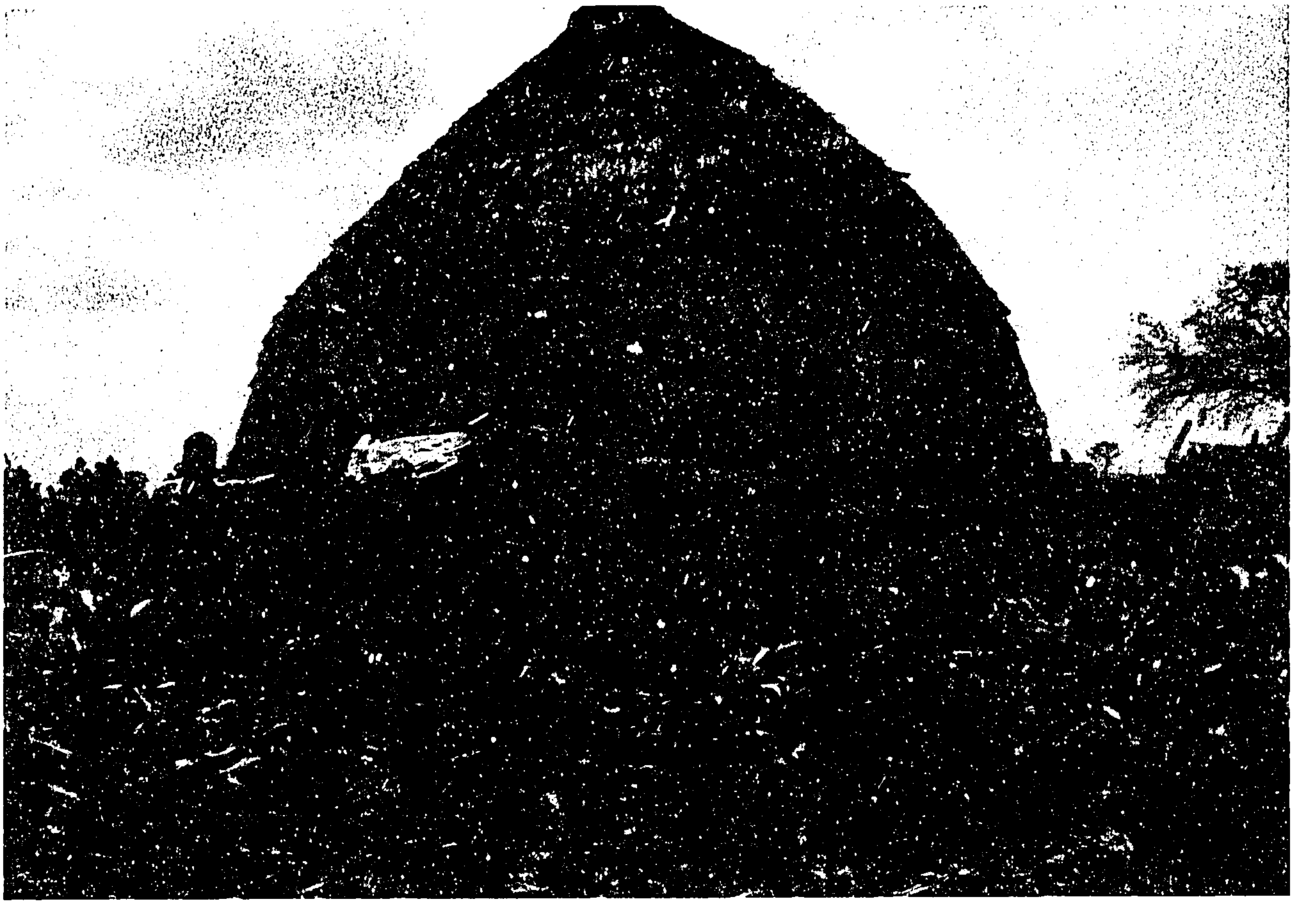


Figure 10. Effect of Phosphorus and Cropping Systems on Pearl Millet Grain and Total Dry-Matter Yield, Sadore, Niger, 1993.

Pearl millet harvest from a plot following different combinations of N, P, K, and S fertilizers. The farmer will harvest 300 kg/ha of pearl millet grain in the $N_0P_0K_0S_0$ plot. Because phosphorus is the most limiting nutrient, the addition of N, P, K, and S in the $N_2P_0K_1S_2$ plot will not increase crop yield. A pearl millet harvest of 1,500 kg/ha resulted from the $N_2P_4K_1S_1$ plot.

The effect of crop residue alone (front plot) and the combination of crop residue and fertilizers (far plot). An important highlight of the research on integrated nutrient management in the Sudano-Sahelian zone is that for sustainable crop production in the region, both organic and inorganic plant nutrients should be applied. The rate of decomposition of crop residues was measured within the metal fence placed in the front plot.



A Nigerien farmer pictured in front of his granary views his crop after the use of fertilizers. His granary will be full this year and his family's food requirement will be met.

crop residue in the more humid regions of West Africa requires further study, and there is a necessity to monitor the dynamics of organic matter turnover in the different soils.

Micronutrient Deficiencies in Semiarid West African Soils — A new study is in progress in the Sahelian and Sudano zones of West Africa to assess the seriousness of micronutrient deficiencies in the West African soils. While the data obtained thus far are sketchy, it is apparent that both legumes and nonlegumes benefit immensely from the application of molybdenum. Pearl millet grain yield and groundnut yield increased by as much as 550% with the application of nitrogen, phosphorus, manure, molybdenum, and carbofuran (to kill nematodes).

Evaluation of Sustainable Agricultural Practices in Togo

The Benefits of Crop Rotation in Increasing Soil Productivity — 1993 marks the fourth year that three of four rotation experiments have been conducted at different locations in Togo (Davié, Amoutchou, and Koukombo). At each location, this experiment was initially installed for a 5-year period. Special attention has been given to fertilizer efficiency, savings on nutrients, and sustainability of crop production.

Research to improve fertilizer efficiency is approached by comparing the production of different rotations involving maize, cowpea, cotton, groundnut, and natural and improved fallows. Each cropping system received the same amount of fertilizer (usually 45 kg of nitrogen, 30 kg of phosphate (P_2O_5), and 15 kg of potash (K_2O)/ha). The treatments include two references: the local farmers' practices (no fertilizer input) and a high level of fertilizer input (90 kg of nitrogen, 60 kg of phosphate [P_2O_5], and 30 kg of potash [K_2O]/ha).

A goal of the research is to find ways to reduce the quantity of fertilizer needed. This is done by comparing the production of treatments where phosphate rock (Togo phosphate fines) is used with treatments where commercial superphosphates are used and where legumes (groundnut, cowpea, and soybean) introduced in the rotation or in the form of applied *Leucaena* leaves are used as substitutes for portions of required nitrogen fertilizers.

As in the *1992 IFDC Annual Report*, special attention has been given to the results of the experiment where crop residues have been managed in different ways (removed, incorporated, mulched on the soil, or composted).

Gross Production From Experimental Plots — During 1993 four rotation trials were conducted on four sites from south to north: Davié, Amoutchou, Kaboli, and Koukombo. This was the first year that an experiment was conducted at the Kaboli site. Maize was the major cereal crop.

Statistical parameters of each trial are as follows:

Average Maize Yield	(kg/ha)	SD (kg/ha)	CV (%)
Davié Rotation 1			
1st season	3,023.14	444.47	14.7
2nd season	2,788.09	393.04	14.1
Amoutchou Rotation 2			
1st season	2,972.37	630.27	21.2
2nd season	1,078.56	222.98	20.7
Koukombo	2,006.51	486.93	24.3

The crops preceding maize in Davié included maize, natural and improved fallow, cowpea, and groundnut. They were grown during the second rainy season. In Amoutchou, in addition to this list of crops preceding maize, cotton was also cultivated. In Koukombo the treatments involving the improved fallows and cowpea were omitted.

The improved fallow treatment involves the cultivation of Crotalaria, a small annual legume. Figure 11 shows maize production at three experimental sites under the different treatments. The amount of applied NPK fertilizer (45-30-15)

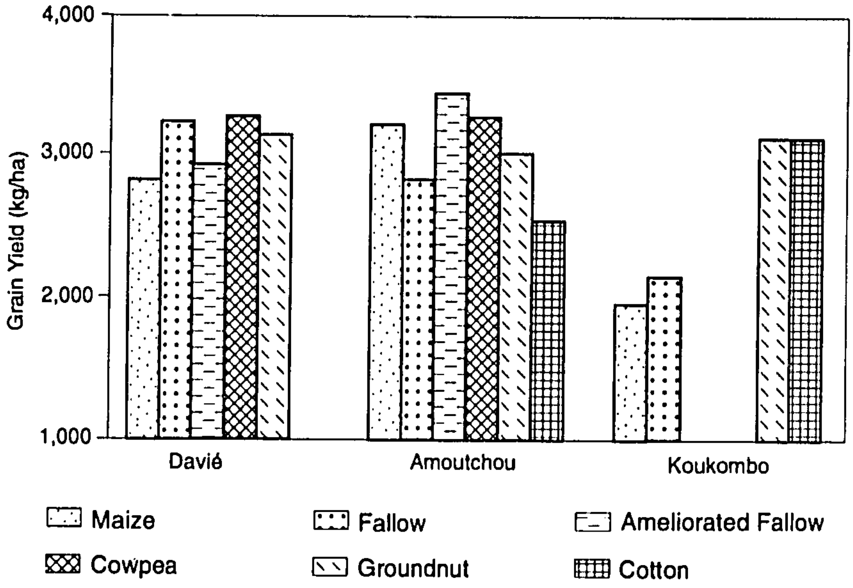


Figure 11. Effect of Crop Rotation on Maize Grain Yield in 1993.

is uniform. For the two sites in the South (Davié and Amoutchou), the cultivation of legumes such as groundnut and cowpea improved the performance of the subsequent maize crop. Similar results were obtained in 1990 and 1991. At Amoutchou the growth of an improved fallow (Crotalaria) resulted in the highest maize production in 1993.

At Koukombo, in the savanna zone of Togo, maize performed significantly better following a crop of cotton or groundnuts. Continuous maize or maize preceded by natural fallow also performed poorly. This effect was first observed in 1992. The benefit of rotation at this site is that it prevents contamination by *striga* (a parasitic weed).

Use of *Leucaena* Leaves — During 1993 application of *Leucaena* leaves provided sufficient nitrogen for maize cultivation (Figure 12). At Davié enough nitrogen was supplied by *Leucaena* for a yield as high as 3,000 kg/ha. At Amoutchou, during the drought of the second growing season, the treatment that received *Leucaena* leaves performed significantly better than the treatment that received only fertilizer. At the northern stations, all of the treatments that received *Leucaena* leaves performed better than in 1992, but their performance was still below that of the treatments that received nitrogen fertilizer.

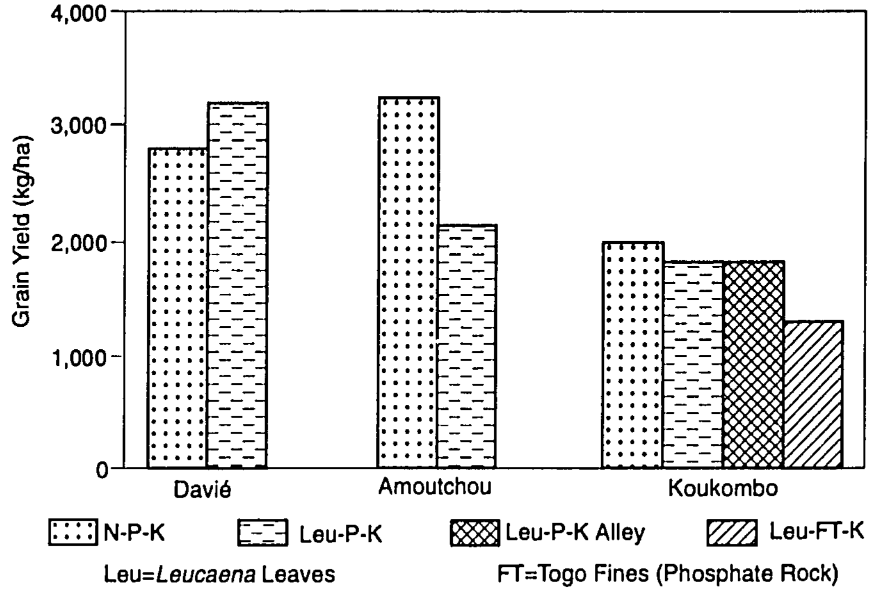


Figure 12. Use of *Leucaena* as N Fertilizer on Maize Grain Production in 1993.

Effect of Togo Fines on Maize Cultivation — Since 1990 some plots have received applications of Togo phosphate fines (very fine raw Togo phosphate rock) in place of commercial phosphate fertilizer at the rate of 30 kg of P_2O_5/ha. With the exception of Koukombo, the phosphate rock performed as well as or better than the commercial superphosphate (Figure 13).

Effect of Crop Residue Management — The treatments that were tested included the removal of straw, the use of straw as mulch, and the incorporation of compost made from straw. Two treatments involved the use of straw or compost at five times the quantity of straw produced in the plots during the previous season. In the two stations of southern Togo (Davié and Amoutchou) during each of the two cropping seasons, the removal of straw led to decreased production. Application of straw as compost was the superior practice. In the north, no significant difference could be found between the different approaches to residue management in this savanna zone experiment site. Information from data generated by these site-specific research station trials is being used to strengthen our work with farmers and national research and extension systems on sustainable crop production in different West African watersheds.

Economic Analysis of Food Crop Fertilization in Some Watersheds in Three West African Ecological Zones

In 1987 IFDC initiated a 5-year Soil Fertility Restoration Project (SFRP) to evaluate various plant nutrients and

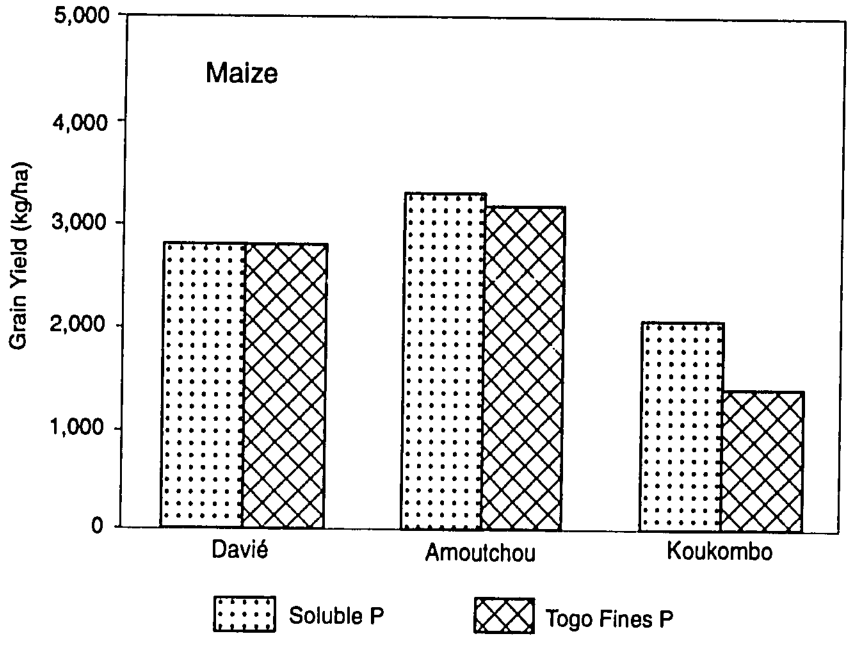


Figure 13. Effect of Togo Fines (Phosphate Rock) as P Fertilizer on Crop Yield in 1993.

assess their benefits for the restoration and sustainability of soil productivity, the evolution of farming systems, and the economies of village communities. The economical return of fertilizers used on food crops was studied as part of this project, which was carried out in three agroecological zones in West Africa — the Sudano Sahelian savanna of southern Niger, the Sudano-Guinea savanna of northern Togo, and the Guinea forest of south-central Ghana. The studies were conducted in association with national research and development institutions, which included the Institut National de la Recherche Agronomique in Niger, the Institut National des Sols in Togo, and Soil Research Institute and the Ministry of Agriculture in Ghana.

Data from on-farm trials conducted during a year characterized by average climatic conditions were used for the analysis. Fertilizer use options were evaluated for the major food crop association in each zone: millet-sorghum-peanut-cowpea in Niger, early and late millet and sorghum in Togo, and maize in Ghana.

Recommendations are based on treatments that allow 50% or more of the users to obtain a profit high enough to achieve a minimum value:cost ratio of 2 when farmers sell all the additional production at harvest. Four recommendable treatments were identified in the three locations: the local recommendation in Ghana that corresponds to N-P_2O_5-K_2O: 45-19-19 obtained by using 15-15-15 and ammonium sulfate; the use of 5 tonnes/ha of manure in combination with 30 kg/ha of P_2O_5 using SSP in Niger; the use of 5 tonnes/ha of manure in combination with 35 kg/ha of P_2O_5 using SSP in Togo; and the use of 15-15-15 with urea to obtain a rate of 60-35-35 in Togo (Figure 14).

Sensitivity analyses were conducted to assess the effects of changes in fertilizer and crop prices on the percentage of fertilizer users that would receive a value:cost ratio of 2 from their investment in fertilizer (Figure 14). These analyses show that changes in fertilizer market prices could be possible in Ghana and Togo where a 30% increase in prices does not affect the fertilizer recommendations. However, no recommendation could be made for Niger if the fertilizer price is set at the level of the Ghanaian price, which is the least subsidized of the three locations. A minimum subsidy of 40% is required to maintain the recommendations (low fertilizer market prices in Niger are due to the supply that comes through the Nigerian border). In Nigeria fertilizers are heavily subsidized.

A policy to promote the use of local resources should benefit the farmers and the national economy. Decreasing the price of the locally acidulated phosphate rock should promote its use (Figure 14).

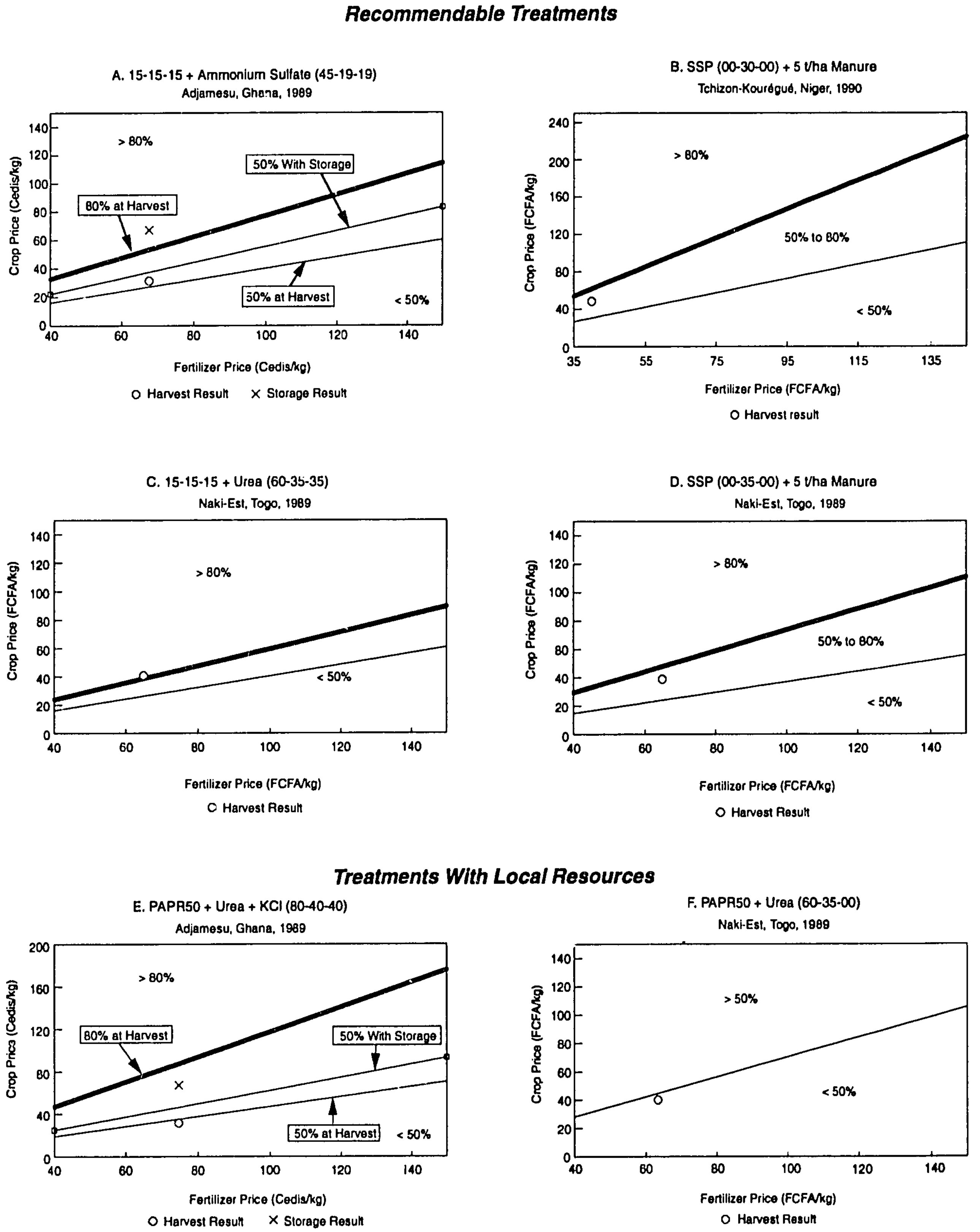


Figure 14. Percentage of Farmers Reaching a Value:Cost Ratio of 2.

In Niger and Togo storage is common, thus, market prices are more stable during the year. Storage of crop output should be supported throughout Ghana as a means to stabilize market prices. However, in Ghana storage is rare and risky due to permanent humidity; thus, market prices fluctuate sharply because crop output cannot be stored and sold later. The four fertilizer treatments evaluated in Ghana become profitable and recommendable when the additional production is stored and sold later at higher prices.

Policy Reform, Market Research and Development in West Africa

Introduction

IFDC has stressed the need for the establishment of enabling policies that would promote increases in fertilizer use. IFDC's policy reform studies are designed to provide policymakers in Africa with relevant information that would guide rational policy choices with respect to fertilizer production, marketing, and use. IFDC assists governments in Sub-Saharan Africa in the development of cost-effective fertilizer marketing strategies through (1) the collection, analysis, and dissemination of fertilizer-related data to countries; (2) the conduct of systematic and detailed studies of the fertilizer sector in individual countries; (3) the collection of up-to-date information on the economic, agronomic, and technological data in an interactive data base available to countries in the region; and (4) the building of national capacities and institutions related to fertilizer policy and internal restructuring of fertilizer supply systems. The Directoraat Generaal voor Internationale Samenwerking (DGIS) sponsors IFDC-Africa's work in policy reform, market research and development.

With funding from the Dutch Government, IFDC-Africa conducts an annual meeting of the African Fertilizer Trade and Marketing Information Network, which attracted 70 delegates from 15 countries in Africa, four European countries, and the United States for the sixth annual meeting in 1993. Shown here at the AFTMIN-6 Meeting is the IFDC-Africa Marketing Team (from left to right), Pim Volkert, Associate Expert; Kossi Dahoui, Associate Economist; Cinty Visker, Associate Expert; Souleymane Diouf, Marketing Specialist; Leon Bodjrenou, Research Assistant; Henny Gerner, Economist/Data Base Manager; and Gisele Dovi, Secretary.

During 1993 IFDC-Africa developed a new fertilizer trade information service for sub-Saharan Africa that contributes to the promotion of transparent, open and competitive fertilizer markets in that region.

Highlights of 1993 Activities

New Trade Information Service for Sub-Saharan Africa

During 1993 IFDC-Africa developed a new fertilizer trade information service for sub-Saharan Africa that contributes to the promotion of transparent, open and competitive fertilizer markets in sub-Saharan Africa. This new service is targeted to public and private fertilizer importers, fertilizer manufacturers, and international fertilizer traders. This service provides public and private fertilizer importers with a better basis for negotiation since they can compare prices and sales services with their colleagues from neighboring countries. In addition, since more manufacturers and international traders are interested in the sub-Saharan market, increased competition and lower fertilizer prices result.

Input — The marketing professionals at IFDC-Africa systematically collect detailed fertilizer trade information at the transaction level. All commodity information available at IFDC-Africa is scanned, and personal contacts with fertilizer procurement officers, traders, public and private importers, and suppliers are made to retrieve the information.

Data Management — A user-friendly trade data base module was developed and incorporated in the IFDC-Africa Fertilizer Information Data base. The collected data are cross-checked prior to entry into the trade data base module. The most important fields in the trade module include buyers, products, prices, quantities, conditions, funding, origin of products, and peculiarities of tenders.

Output — After the information is entered into the system, the data base can be consulted to make overviews and analyses. One overview table with current information on fertilizer transactions to sub-Saharan Africa, derived from the trade data base module, is included in the monthly bulletin entitled the *African Fertilizer Market*, which IFDC-Africa publishes in French and English. Cross-tabulation can easily be retrieved and presented in tables or figures.

Fertilizer Markets to Meet Needs of West African Farmers

Because farmers in sub-Saharan Africa apply fertiliz-

These farmers need access to nutrient sources that are affordable and that maintain soil fertility and lead to sustainable agricultural production systems.

ers at such low levels, the soil nutrients that are removed by plants, lost through erosion, and other factors are not replenished. These farmers need access to nutrient sources that are affordable and that maintain soil fertility and lead to sustainable agricultural production systems. Their choices of different fertilizer types and forms should be based on socioeconomic and agronomic factors. The reality, however, is that farmers' selections of fertilizers are often based on conditions imposed by suppliers/manufacturers, rather than on their needs.

As governments withdraw from the business of supplying inputs, the private sector is expected to play a larger role in the importation and domestic marketing of fertilizers in sub-Saharan Africa. If the private sector is to offer farmers a product that meets their needs, constant monitoring of the different products (choices and specifications) that are imported into the region is essential. The governments have a role in ensuring that adequate levels of quality control are maintained. Adequate quality control protects both the farmers and the importers.

In several countries of sub-Saharan Africa straight fertilizers (fertilizers that contain one or two nutrients), blended fertilizers, and fertilizers made by the nitric acid route are excluded from the fertilizer market. The use of local materials as fertilizers is of marginal value. This factor limits the farmer's choice, increases the costs of those fertilizers available on the local markets, and wastes nutrients.

Sub-Sahara African farmers need quality fertilizers that cover their needs at the lowest possible price.

Sub-Sahara African farmers need quality fertilizers that cover their needs at the lowest possible price. This situation will be best achieved in a competitive market that is made up of many suppliers. Sub-Saharan Africa should consider readjusting the selection of fertilizer types and specifications. The excess world fertilizer capacity, the variety in fertilizer production processes, and the availability and value of local resources should be incorporated in the socioeconomic and agronomic arguments that determine the selection of fertilizers in the region.

Emergence of Bulk Blending and Blended Fertilizers in West Africa — The search for less costly fertilizer types and forms accelerated the introduction of an alternative process for the production of compounds: bulk blending. Blending is physical mixing of two or more straight fertilizers that are chemically nonreactive or minimally so. The products that come from a blending plant are called blended fertilizers or blends. A well-produced blend gives the same agronomic results as a quality complex fertilizer.

Seven blending plants are presently operating in West Africa: five in Nigeria, one in Côte d'Ivoire, and one in Senegal. A blending plant in Benin will soon be operational, and in Cameroon a private businessman is seeking funding to establish a blending unit.

To stimulate the discussion of blending in sub-Saharan Africa, IFDC-Africa and the Ghana Ministry of Food and Agriculture organized the sixth annual meeting of the African Fertilizer Trade and Marketing Information Network in 1993 in Ghana. During this meeting 70 participants from 15 countries in Africa, four European countries (Netherlands, France, Finland, United Kingdom), and the United States discussed the principles of bulk blending and to what extent blended fertilizers could be an alternative to the traditionally used complex fertilizers of sub-Saharan Africa.

One of the merits of the blending process is its flexibility; a blender can offer specific formulas tailored to crop and soil conditions at less cost compared with granulation due to a lower investment and utility cost per tonne of product. This means that the properly operated blending process can be used to meet farmers' needs. The buyers considering blends can take advantage of this system by upgrading their current formulas with products containing the same ratio of nutrients but with higher nutrient contents, thus providing savings in transport and application per unit of plant nutrients. For example, the authorities in Burkina Faso selected a ratio of 1-2-1 (nitrogen, phosphorus, potash) for food crops in the noncotton region; the maximum possible grade was 15-30-15. This was subsequently produced by the Abidjan-based fertilizer company. Another option is that buyers select a lower-than-maximum grade and request a special filler, such as dolomitic limestone granules. This method is used in Nigeria to balance the acidifying effect of the fertilizer. It can also serve as a useful source of secondary elements. If possible, bulk-blending units need to be encouraged to use indigenous resources to stimulate the local economy.

Segregation is one of the major problems in dealing with blends. Blenders (and consequently buyers) can reduce segregation by defining not only the particle-size range (as is done in Mali and Burkina Faso) but also the particle-size variation.

Bulk blending is only a viable option in West Africa if the blender offers a quality blend at affordable costs. The most critical factor in blending is the selection and cost-effective procurement of raw materials that are chemically compatible and match in particle size. This means that the blender needs to have a sound knowledge of the international market of the raw materials and must be able to procure the raw materials in quantities sufficient to benefit from the economies of scale of sea freight.

Although quality blends are alternatives to the traditionally used complex fertilizers, many West African countries are reluctant to allow blends into their markets. Some of the cotton organizations allow only a limited quantity of blended fertilizers or they may add bonus points for complex fertilizer. In Ghana, the 40% nitrate nitrogen specification for compounds creates a hidden obstacle for the introduction of blended fertilizers from the neighboring Côte d'Ivoire.

Several countries, however, are testing the blended fertilizers; for example, in 1992 Burkina Faso and Mali introduced blends to limited areas and monitored the quality of the blends and farmers' reactions.

Policy Analysis in Ghana and Mali

Beginning in 1987 IFDC became involved in a project that focused on Ghana, Mali, and other African countries. The project was entitled "Fertilizer Policy Research Program for Tropical Africa" and was funded by USAID. Under the project, a fertilizer policy research group was established at the Institute of Statistical, Social, and Economic Research (ISSER), University of Ghana, Legon, Ghana, and the Institut d'Economie Rurale in Mali to strengthen the institutional capacity for policy analysis, formulation, and implementation. Initially, the group is focusing on the following broad themes: food security and fertilizer use; agronomic potential of fertilizer use; constraints on fertilizer use; and policy environment and fertilizer sector development.

The technological transformation of Ghana's agriculture will need new technologies, practices, and methods of cultivation.

In cooperation with ISSER and the International Food Policy Research Institute, IFDC conducted a study to evaluate the impact of the policy environment on fertilizer sector development in Ghana and Mali and, thus, to understand the factors responsible for Ghana's low levels of fertilizer use and suggest measures for promoting efficient, equitable, and environmentally sound fertilizer use. The results of their study clearly bring out that a conducive and stable policy environment is essential for promoting growth in fertilizer use and thereby ensuring food security and environmental protection.

Ghana's population is projected to increase from 14.1 million in 1990 to 18.7 million in 2000. This growth in population along with growth in per capita income and urbanization will create increased demand for food, fiber, and raw materials and will therefore make intensive agriculture based on modern technologies, including fertilizers, indispensable.

Ghana's Mid-Term Agricultural Development Programme stresses that Ghana's agricultural sector must grow by at least 4% per year to meet the increasing challenges of feeding and providing adequate nutrition for the growing population, creating employment, providing raw materials for industrial development, promoting regional development, and earning foreign exchange.

The achievement of 4% or more annual growth in agricultural output is possible provided new technologies are adopted and adequate physical, institutional, and human resources are developed. The technological transformation of Ghana's agriculture will need new technologies, practices, and methods of cultivation. Among such measures, fertilizer use will play a lead role. Increased fertilizer use will be required for adoption of improved crop cultivars and replenishment of nutrients removed by crops under continuous cultivation.

In spite of the growing need for increased food production, Ghana's fertilizer use levels are rather low. In 1990 Ghana used less than 5 kg/ha of plant nutrients and replenished less than one-seventh of the plant nutrients removed by dominant crops. Such a negative balance in the nutrient account leads to the degradation of the resource base and food insecurity in the long run.

The Ghana study produced three major findings. First, macroeconomic policy played an important role in constraining growth in fertilizer use. During the 1980s rapid devaluation of the domestic currency resulted in over 25,000% increase in fertilizer prices. The removal of subsidies also contributed to this process. Consequently, fertilizer use decreased from 30,000 nutrient tonnes in 1980-82 to 10,000 nutrient tonnes in 1988-90.

Second, the privatization of fertilizer marketing, which was initiated in the late 1980s, was unsuccessful because the macroeconomic and price instability discouraged private dealers from participating in the fertilizer market. Lack of credit for farmers and fertilizer dealers also contributed to this outcome.

Third, the simultaneous introduction of exchange rate liberalization and subsidy removal programs does not promote growth in fertilizer use nor does it encourage private sector participation. Proper sequencing and phasing should be developed for each policy and, if needed, some safety nets should be provided to counteract the undesirable social impacts.

During 1993 a study was conducted to assess the policy environment and fertilizer sector development in Mali. The study resulted in a number of findings.

Growing population and the practice of shifting cultivation have intensified the problem of land degradation and desertification. Unless increased efforts are made to control soil erosion through proper nutrient management, water harvesting, and other measures, resource degradation will become an intractable problem. Hence, efficient and environmentally sound fertilizer use will play an important role in providing increased crop production and in preserving the natural resource base.

Fertilizer use grew at 17.7%/year during the 1970s and 4.9%/year during the 1980s. In absolute amounts, total fertilizer use was 2,547 nutrient tonnes in 1970; 14,928 nutrient tonnes in 1980; and 24,470 nutrient tonnes in 1990. Although total fertilizer use increased at 4.9%/year during the 1980s, there was little growth in per-hectare fertilizer use, which increased from 8.0 kg/ha in 1980 to 8.7 kg/ha in 1990. Thus, most of the growth in total fertilizer use was due to an increase in fertilized area.

Mali's nutrient use is based on high-analysis fertilizers such as DAP, urea, and the cotton fertilizers.

Fertilizer use in Mali is highly concentrated in a few "Operations de Developpement Rural." In 1990 the Compagnie Malienne pour le Developpement des Textiles (CMDT) accounted for 81% of total fertilizer use. Office du Niger and the Office Haute Vallee accounted for 13% and 3%, respectively. Thus, these three rural development operations accounted for over 95% of the total fertilizer use. Although these three organizations cover most of the highly productive area of southern Mali, efforts are needed to promote fertilizer use in other parts of the country where the resource degradation problem is serious.

Mali's nutrient use is based on high-analysis fertilizers such as DAP, urea, and the cotton fertilizers. These three products accounted for over 90% of total nutrient use in 1990. In this respect, Mali is ahead of many other West African countries, including Ghana, that rely heavily on low-analysis fertilizer products.

The macroeconomic policy was not as severe a constraint on fertilizer use in Mali as it was in Ghana during the 1980s. Because Mali is a member of the West African Monetary Union, its currency is easily accepted in most of West Africa and France. Also, Mali has imported fertilizers from Senegal and Côte d'Ivoire where the currency is the CFA franc as it is in Mali. Nevertheless, foreign aid has played an important role in supplying fertilizers.

Fertilizer use was subsidized in the 1970s. However, fertilizer subsidies have been phased out as a part of structural adjustment programs. Only local phosphate rock was subsidized.

Although Mali has phosphate rock (Tilemsi phosphate rock), which is suitable for direct application, it has not become popular with the farmers. To promote its use, CMDT subsidizes its price by 60%. Factors constraining direct application of this phosphate rock and its economic feasibility should be explored in future research.

Nominal prices of both crops and fertilizers have increased over time. However, because subsidies have been removed and crop prices have decreased, real prices of fertilizers (terms of trade) have increased. Real prices of all nutrients were higher in 1990 than they were in 1980 for all crops except paddy rice.

Mali's pricing policy ensured subsidized and uniform prices throughout the country. However, this policy was changed in the 1980s. Consequently, prices differ from one zone to the other. For example, nominal and real prices of fertilizers were much lower in the CMDT zone than in the other rural development operations. This is primarily because CMDT benefits from the economies of scale in purchasing its fertilizer requirements.

Until 1980, the Société de Credit Agricole et Equipement Rural (SCAER) was responsible for importing fertilizers for all rural development operations. Because of mounting losses and deficits, SCAER was dissolved in 1980/81. Thereafter, individual rural development operations arranged for their fertilizer supplies. This change in policy has created opportunities for some private agencies and private importers to import and distribute fertilizers. In some of the rural development operations, village associations have assumed the responsibility for distributing fertilizers.

Credit for purchasing fertilizers is provided by both rural development operations and the Banque Nationale de Developpement Agricole at an interest rate of 10%-14%/year. Because many of these organizations promote trade-in-kind, i.e., exchanging fertilizers for crop produce, most of the loans for fertilizers are only for one cropping season. At the farm level in the CMDT zone, credit does not seem to be a constraint. However, further research is needed in this area.

Mali has not created any inefficient fertilizer production facilities, nor has it built protective walls to safeguard and promote the use of its indigenous Tilemsi phosphate rock. However, Mali should explore the possibility of using its phosphate rock in blending and compaction operations. The use of this phosphate rock should also be encouraged to restore and maintain soil fertility at reasonable levels so that soils do not become degraded. Mali's environmental policy seems to be moving in the right direction in this area.

Outside the CMDT zone, and in other parts of the country not covered by the rural development operations, research and extension efforts should be strengthened.

Currently, there is no policy in existence to promote the development of private sector dealer networks for fertilizer marketing and distribution. Institutional and infrastructural facilities should be developed to train dealers in the fertilizer business.

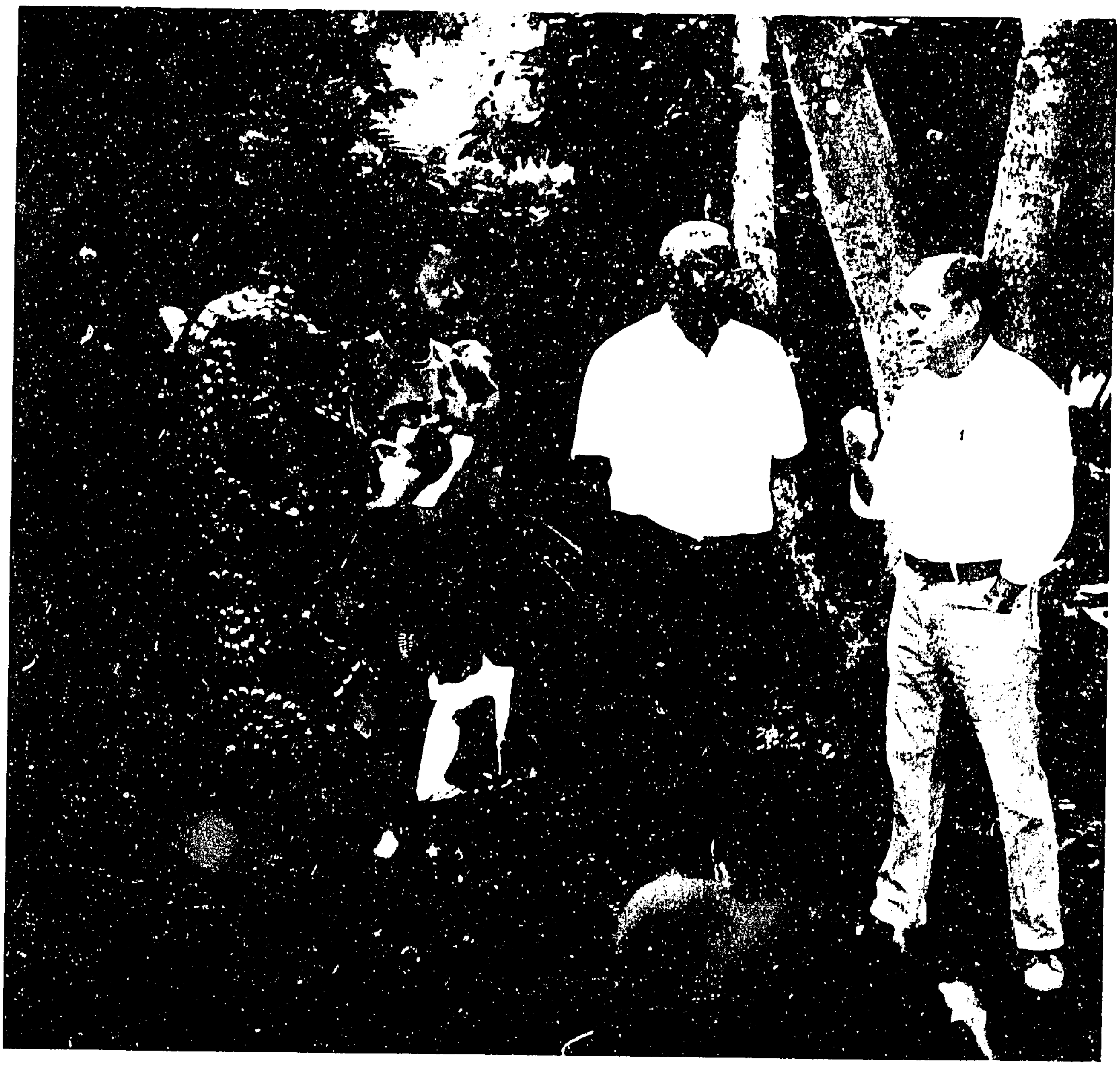
Fueling Sustainable Agricultural Growth Through Capacity Building

Introduction

The term, "capacity building," implies the empowerment of people to be self-reliant. It involves strengthening national capacities of both institutions and individuals. It encompasses both public and private institutions. In assisting developing countries to achieve food security, we must first help them analyze their problems, determine the necessary course of action to resolve these problems, and mobilize the required resources to complete the necessary tasks. In the end, we must leave our developing-country partners stronger and more capable of carrying on their work toward sustainable agricultural development.

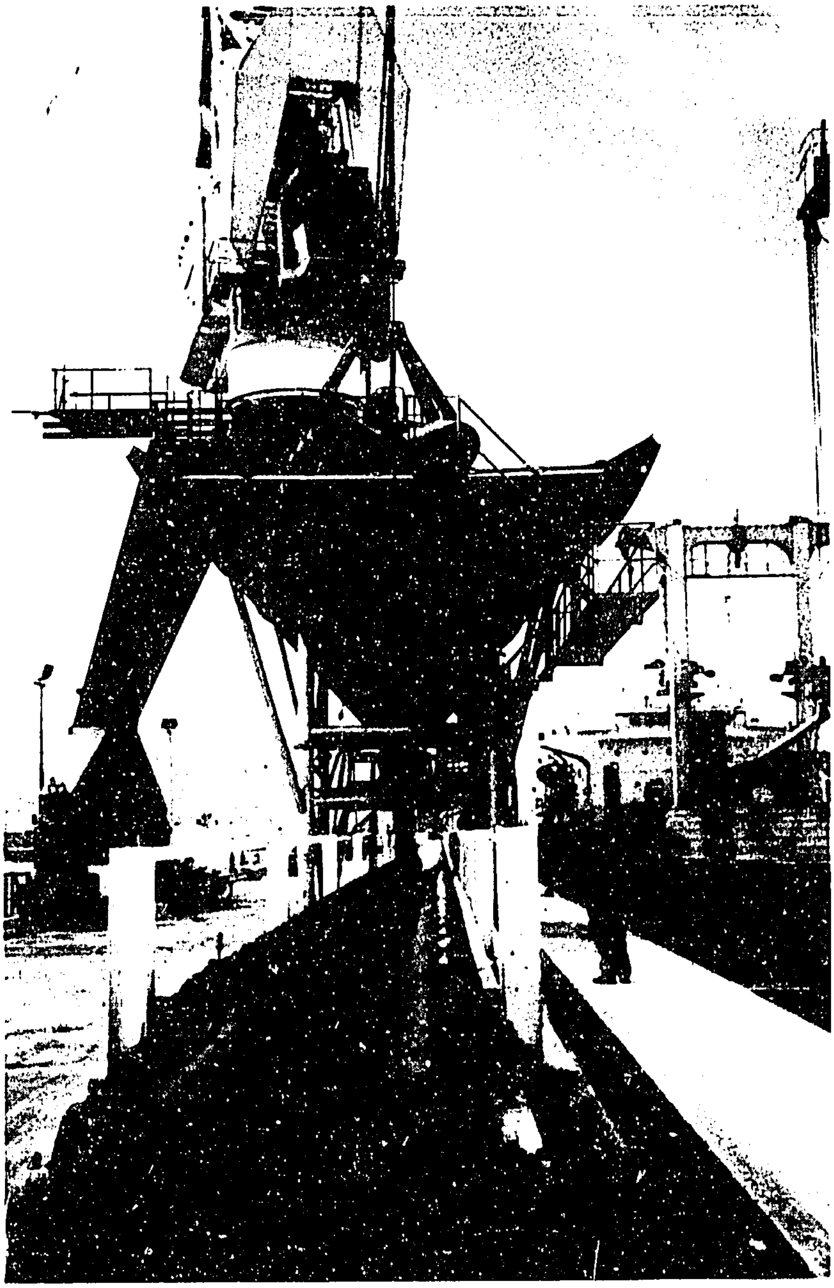
During 1993 IFDC continued its efforts in capacity building by transferring technology to institutions in the developing countries and training a total of 436 individuals from 66 countries through 10 formal training programs.

In the "Granja Loma Linda," an International Teaching and Learning Center, the Director Elias Sanchez gives a demonstration of his "inducing" extension approach through a lively course on soil science. His audience includes IFDC-Africa staff and representatives of national agricultural institutions and universities from throughout Africa, who visited Latin America to learn new ways to enhance the role of agricultural extension in optimizing farmers' capacity to improve their lives. This study tour was sponsored by the Kellogg Foundation.



Institutional Capacity Building Through Technology Transfer

Colombia — During 1993 IFDC provided technical assistance to Abonos Colombianos S.A. (ABOCOL) through which ABOCOL has been able to increase and improve its production capacity. ABOCOL manufactures nitrophosphate-based granular NPK fertilizers in Colombia. The technical assistance included the conceptual engineering design, process development through pilot-plant testing, preparation of the basic process engineering design, review of the detailed engineering design, precommissioning inspection, and startup supervision for a new reaction and neutralization unit for their nitrophosphate production facility. The new process unit permits a capacity increase of about 80% while at the same time it increases efficiency in the use of raw materials, decreases environmental pollution, decreases maintenance requirements, and permits longer and more steady runs of fertilizer grades more suited for the Colombian agriculture. The new unit is now in full and successful operation.



Venezuela — Offloading imported bulk fertilizer at the private storage and handling terminal of Venterminales, near main port of Puerto Cabello.

Venezuela — During 1993 IFDC completed Stage I of a comprehensive study for Petroquimica de Venezuela S.A. (PEQUIVEN). This study covers the company's operations from production through distribution and marketing. PEQUIVEN is a subsidiary of Petroleos de Venezuela S.A. (PDVSA), dedicated to the production of fertilizers in its industrial complex located in Morón, Venezuela. The study is intended to assist PEQUIVEN in developing a long-term strategy and implementation plan for a commercial fertilizer operation that is competitive with international market forces. The work performed focused on a technical evaluation of the phosphoric acid and DAP/NPK granulation units.

Other components of the study will cover the commercial analysis of the fertilizer business unit, including an in-depth analysis of the marketing of fertilizers in Venezuela and will later establish an inventory of companies to whom an association with PEQUIVEN could be of commercial interest.

Albania — As part of IFDC's privatization project in Albania, an in-depth study was completed for the Fier Nitrogen Fertilizer Factory (FNFF) located in Fier, Albania. The study found that this company has the potential of supplying all of Albania's nitrogen fertilizer needs at competitive international prices while providing material for exports. The study also determined the physical requirements to bring the FNFF back to a sustained and economically effective operation. The most critical problem faced by the FNFF is the shortage of natural gas in Albania. However, a study performed by a petroleum company under contract with IFDC indicates that, with high expectation for success and a relatively small investment, two natural gas wells in the Delvina gas fields can produce enough natural gas for the economic operation of the FNFF. The IFDC team recommended a stepwise investment and technical assistance program for the factory that will ensure that the issues of natural gas supply, domestic demand for nitrogen fertilizer, environmental stewardship, and the cost-effective production of nitrogen fertilizer are fully addressed. It appears that privatization of the FNFF may be successfully accomplished once the supply of natural gas is made more reliable.

In addition, with funding from USAID IFDC completed a technical and economic evaluation of the Lac superphosphate plant facilities in Albania. The study also included a marketing component and a review and assessment of the raw materials. Consideration was given to the production of new (modified) products to improve the competitiveness of the plant in domestic and regional markets. The study concluded that the Lac factory would not be competitive in a free market environment.

Mexico — At the request of FERTINAL S.A., Mexico City, IFDC provided two phosphate rock experts to examine the Baja California phosphate rock deposit, which FERTINAL recently purchased. The IFDC experts visited the mine and beneficiation plant to evaluate the mining and processing operations and evaluate testwork that the engineering department had performed previously. It was concluded that the mining and processing operation produces phosphate rock concentrates at costs significantly below those of comparable products available on the world market. FERTINAL would like to decrease production costs, increase production, and/or extend the life of the reserves as much as possible. IFDC made a number of recommendations to assist FERTINAL in achieving these goals.

Costa Rica — At the request of Fiduciaria de Inversiones Transitorias (FINTRA), IFDC completed a reassessment of the market value of Fertilizantes de CentroAmérica S.A., (FERTICA) in Costa Rica. This information is to be used as a basis for the privatization of FERTICA, the major fertilizer producer in Costa Rica. The reassessment was necessary because the local fertilizer industry conditions had changed considerably since the first assessment, which was also performed earlier by IFDC. After this last assessment, the company was advertised for sale by the Government of Costa Rica.

Egypt — IFDC continued to provide technical assistance to the Egyptian Fertilizer Development Center (EFDC) in the construction of a pilot plant for the production of different types of granular fertilizers. IFDC had previously prepared the basic process design for this unit, which will serve as a tool for EFDC to perform development and research work and to assist in the training of personnel from the Egyptian fertilizer industry. IFDC reviewed fabrication drawings and inspected the equipment and construction site. After the construction is complete, IFDC will participate in the startup of the facility and in the training of its operators. This is expected to occur during the first half of 1994.

Individual Capacity Building

Formal Group Training Programs

Data Collection, Analysis, and Projections for Agribusiness

A 3-week program on Data Collection, Analysis, and Projections for Agribusiness was conducted during 1993 at IFDC Headquarters, Orlando/ Lakeland (Florida), Chicago (Illinois), and Washington, D.C. It was attended by 9 economists and statisticians from Albania, Cameroon, Ethiopia, Ghana, Indonesia, Pakistan, and Thailand. At Headquarters, presentations on economic analysis, sampling, regression, and projections were made through hands-on practice on computers. In Florida, participants were briefed on the statistical organization of a state and its operations. In Illinois, participants discussed the need and use of data for commercial operations. In Washington, D.C., the participants learned the federal system of agricultural data collection, processing, tabulation, interpretation, and use. For this, they discussed agricultural statistics with officials at the National Agricultural Statistics Service, Foreign Agricultural Service, Economic Research Service, and U.S. Census Bureau. The participants were also exposed to the data management system of industry associations, namely, The Fertilizer Institute.

Deregulation and Privatization Policies to Reform Agribusiness Markets

IFDC organized a workshop on Deregulation and Privatization Policies to Reform Agribusiness. Part one of the workshop was a training component conducted at IFDC Headquarters, and part two comprised the formal workshop segment in Washington, D.C. The program attracted 14 participants from 11 countries. The countries represented included Albania, Bangladesh, Costa Rica, Estonia, Ethiopia, India, Indonesia, Malawi, St. Lucia, United States, and Zambia. Speakers at the workshop were distinguished experts in deregulation and privatization. The proceedings are being printed and copies will be made available to delegates and other interested organizations.

Computer Simulation for Crop Growth and Nutrient Management

A program on Computer Simulation for Crop Growth and Nutrient Management was organized at IFDC Headquarters during 1993. The twenty-two participants attending the program represented 18 organizations from 17 countries — Albania, Brazil, Colombia, Egypt, Guatemala, Jordan, Malawi, Mexico, Morocco, Norway, Peru, Philippines, Republic of South Africa, Thailand, Tunisia, United States, and Zambia. The program made extensive use of several existing crop models such as the CERES models for rice, sorghum, maize, and wheat and the GRO models for peanut, soybean, and dry beans. Models were integrated into the decision support system for agrotechnology transfer software packages.

Nitric Acid-Based Fertilizers and the Environment

In cooperation with International Fertilizer Industry Association and the European Fertilizer Manufacturers' Association, IFDC organized an international workshop on Nitric Acid-Based Fertilizers and the Environment in Belgium. The 61 delegates who participated in the workshop represented 25 countries. The workshop dealt with the environmental issues affecting fertilizer production and agricultural development on a global basis, agronomic and environmental issues pertaining to nitric acid-based fertilizer products, environmental issues at production sites, the role of engineering and technology in mitigating environmental impacts, and issues unique to Eastern Europe, the former Soviet Union, China, and selected newly independent states. The workshop discussed alternative nitrogen sources and management practices.

Presentations in the workshop were made by representatives of numerous international and commercial organizations. The proceedings of the workshop are being prepared, and copies will be made available to the delegates and to others interested in the environmental impact caused by the production and use of nitric acid-based fertilizer products.

Modern Techniques in Fertilizer Distribution and Handling

A 3-week traveling program on Modern Techniques in Fertilizer Distribution and Handling was organized in Europe. Seventeen fertilizer logistics managers representing 13 organizations from Bahrain, Dominican Republic, Egypt, India, Indonesia, Saudi Arabia, Turkey, United Arab Emirates, and Zimbabwe participated. The program began in Nottingham (England) and concluded in the Hague (Netherlands). The participants were provided an opportunity to visit the facilities that manufacture equipment for loading and unloading slings, portable weighing and stitching machines, and palletizers. They also observed the loading and unloading of bulk and bagged fertilizer at Rotterdam and Antwerp ports. Discussions with host organizations added to the knowledge of the participants. Participants traveled from Nottingham to Slane (Ireland), Rotterdam (Netherlands), Antwerp (Belgium), and Oelde and Beckum (Germany).

Agroeconomic Evaluation for Development of Fertilizer Recommendations

A program on Agroeconomic Evaluation for Development of Fertilizer Recommendations was held in the Netherlands. Fifteen agronomists, soil scientists, and economists participated. They represented 14 organizations from 14 countries — El Salvador, Guyana, India, Indonesia, Kenya, Malawi, Nigeria, Pakistan, Philippines, Poland, Republic of South Africa, Romania, Rwanda, and Saudi Arabia. The participants increased their knowledge and understanding of the statistical and economic analysis of fertilizer use data for making sound recommendations. Practical exercises were used to develop the skills of participants in the analysis of experimental data, regression analysis, marginal analysis, production functions, and crop simulation models.

Marketing of Fertilizers and Other Agri-Inputs

A program on Marketing of Fertilizers and Other Agri-Inputs conducted at IFDC Headquarters attracted nineteen marketing managers from 15 organizations in 7 countries — Albania, Bangladesh, Burundi, Dominican Republic, India, Indonesia, and Nigeria. The program covered fertilizer marketing, agronomy, promotion, strategic marketing, planning, management and communication, distribution and handling, dealer development, and farmers' needs. Using the IFDC computer-assisted fertilizer marketing simulation exercise, the participants gained experience in directing a marketing company in a competitive and free market economy.

Three field trips were made to Mississippi State University to study seed technology; the Midwest to observe the operation of Farmland (a large cooperative organization that competes with private companies for customers, farmers, and dealers); and Florida to study the mining, production, and transportation operations of the IMC Fertilizer, Inc. The participants also visited successful tomato growers in the area.

Plant Nutrient Management for Sustainable Agriculture

At IFDC Headquarters, a program on Plant Nutrient Management for Sustainable Agriculture was attended by 10 agronomists, soil scientists, and researchers representing 8 organizations from 8 countries—Bangladesh, Brazil, Burundi, Ecuador, Guatemala, Nigeria, Philippines, and Zambia.

The program addressed the challenge of maximizing the efficiency of nutrient inputs (fertilizers and manures) while minimizing any potential detrimental impact they may have on the environment and maintaining the integrity of the resource base. In addition, this training exercise strengthened the participants' awareness of issues pertaining to sustainability of agricultural production.

Besides IFDC professional staff, program faculty included recognized experts from international and U.S. organizations. An added feature of the program was a field trip to the University of Illinois where participants observed long-term experiments.

Indigenous Resource Development for the Fertilizer Sector

The first week of a 2-week workshop on Indigenous Resource Development for the Fertilizer Sector was spent at IFDC Headquarters and the second week in Tampa, Florida (U.S.A.). The workshop's twenty delegates represented 18 organizations from Albania, Canada, Estonia, Ethiopia, Germany, India, Kenya, Nigeria, Saudi Arabia, Sri Lanka, Tanzania, Thailand, Zambia, and Zimbabwe. The Workshop deliberations were conducted during seven technical sessions and dealt with the world fertilizer industry, indigenous resource development, technical and economic aspects of indigenous resource development, and environmental considerations in indigenous resource development. Field trips to view phosphate mining, production, and land reclamation in Florida's phosphate district supplemented the deliberations.

Fertilizer Marketing

In cosponsorship with the Department of Agricultural Extension, Ministry of Agriculture and Cooperatives, Thailand, a training program on fertilizer marketing was conducted in Bangkok. Thirty-eight marketing managers from 24 organizations representing 10 countries participated in this program. The countries were Bangladesh, Ghana, India, Malaysia, Mongolia, Pakistan, Saudi Arabia, Sri Lanka, Thailand, and Zambia.

The program dealt with the four components of marketing, e.g., product, pricing, promotion, and place; communication and management; agronomy; and marketing of seed and plant protection chemicals. The role of privatization and deregulation of fertilizer marketing was also addressed. Visits were arranged to Thai Central Chemical Company, their shipping operations, and dealers. Officials from the Fertilizer Advisory Development and Information Network for Asia and the Pacific (FADINAP), FAO, Thai Ministry of Agriculture, Thai Central Chemical Company, Northeast Agro Industry, Ciba-Geigy, and Cargill Seeds Co., assisted IFDC faculty in the presentations. The IFDC Alpha computer simulation exercise allowed the participants to develop marketing strategies in a free-competitive situation.

Train-the-Trainer Project in West Africa

A 1990 survey conducted by IFDC-Africa showed that two out of three nationals in the West African Fertilizer Management and Evaluation Network (WAFMEN) considered lack of practical training in statistical data analysis as a major constraint that limited their performance as scientists in the respective National Agricultural Research and Extension Systems (NARES).

Appropriate skills in data management, especially in statistical analysis of agronomic data, are essential if agronomists are to make good interpretations of their data. Without such analytical skills, agronomists cannot, regardless of the data generated, provide farmers with reliable fertilizer recommendations to increase crop production. Until recently, most scientists in WAFMEN countries depended on IFDC to handle much of the required statistical assessment of their data.

To reduce direct dependence on IFDC while strengthening the capacity of the NARES to carry out more effective research/extension programs, IFDC-Africa organized in 1993, a series of workshops on fertilizer data analysis with the support of the International Development Research Centre (IDRC). A train-the-trainer approach was used because it was one of the most appropriate ways to facilitate the transfer of knowledge and acquired skills from the trained participants to their colleagues in the selected countries. Initially, eight national scientists were trained at IFDC-Africa in Lomé, Togo. Thereafter, each trained participant was required, upon return to his/her country, to organize, with the assistance of IFDC-Africa, similar workshops for colleagues interested in being trained in statistical data analysis. A total of 25 agronomists were trained. Thus, because of this approach IFDC-Africa was able to reach, directly and indirectly, a relatively greater number of participants than available resources in the project would have allowed.

Technically, the workshops were aimed at instilling in the participants practical hands-on skills in basic statistical methods for evaluating agronomic data. Topics covered during these workshops ranged from simple analysis of variance, mean separations, multiple correlations/regressions, and missing data. In addition, participants were taught how to apply computer software to design their own trials and plot layouts prior to actual planting.

National scientists who participated in these workshops were from Benin, Burkina Faso, Ghana, Mali, Nigeria, and Togo. Because each trained participant is required to help train at least two other colleagues, the overall impact of this program has already exceeded the initial project expectations.

In late 1993 the participants met in Lomé for a post-project evaluation. The participants reported that they are now able to provide better services to their fellow scientists, extension personnel, and more importantly to farmers in their respective countries. Thus, through this train-the-trainer project, IFDC-Africa has helped alleviate one important research bottleneck, which has been undermining much of the

Recognizing the importance of the human factor in the development process, IFDC explores ways to enhance the role of extension work...

A young Honduran farmer briefs the IFDC-Africa group on how he takes care of his soil using crop residues, farm manure, and mucuna as a cover crop.

progress needed to improve agricultural production in West Africa.

Study Tour of Central America by African Development Specialists

Recognizing the importance of the human factor in the development process, IFDC explores ways to enhance the role of extension work in optimizing farmers' motivation and capacity to improve their lives and environments.

In 1993 at the request of IFDC-Africa, seven development and extension professionals of sub-Saharan Africa participated in a South/South study tour sponsored by the Kellogg Foundation. It was an occasion to have a firsthand view of development programs that deserve to be tested and eventually promoted in African countries having similar constraints and environments.

The 1-month study tour involved visits to Mexico; Honduras; Battle Creek, Michigan (U.S.A.); and Washington, D.C. (U.S.A.) The sites visited included national and international research organizations, rural development programs, farmers' fields, and small local enterprises.

Through meetings and discussions, the tour's participants collected a package of innovative ideas, concepts, and methods that have definitely changed their vision of rural work and will surely affect their way of dealing with farmers. The efforts observed go well beyond the framework of technology transfer; the main thread actually is capacity building to foster self-development in rural areas.

In Mexico and Honduras, the group met with dedicated professionals and determined farmers who are cooperatively designing and implementing rural development strategies based on two guiding principles: sustainability and self-reliance.

Sustainability: To Reduce Dependence on External Inputs — Emphasis is on organic matter maintenance and the use of local fertilizer resources and practices such as mixed cropping, recycling of wastes, and integrated farming that involves crop and cattle production and agroforestry. This approach is especially relevant in countries struggling with the devaluation of the West African franc (CFA franc), which has resulted in significant increases in prices for external agricultural inputs.

Self-Reliance: To Reduce Dependence on External Assistance — Farmers are trained to prepare and organize themselves to meet changing development situations at both the individual and community levels. This especially implies controlling the financial factor, which is the most limiting constraint in rural areas. In Puebla, Mexico, development initiatives revolve around a credit union. In response to new problems arising as a result of increased crop production, the establishment of a credit union provided the financial resources for the creation of several microenterprises through which farmers could control their production and manage the marketing of farm produce and byproducts. The ultimate goal of the Plan Puebla Strategy is to empower farmers to master the factors that affect their production and livelihood.

This new approach to rural development as an empowering process confers a key role to extension work. The extension workers' mission is not simply to deliver ready-made technology packages but to help farmers think of adequate solutions and make appropriate decisions. Extension workers are responsible for helping farmers develop their innate capacity for innovative change. In Loma Linda (Tegucigalpa), extension means developing farmers' minds so that they can better understand and master their circumstances and environments.

In this new context, researchers are forced to leave their laboratories and meet with farmers and extension workers in the fields. Communication is everybody's business when it comes to bringing scientific concepts and abstract principles within the reach of farmers. The participants were even amazed to discover in this arena an unexpected actor, the private sector, which plays an important and successful role in agricultural extension in Central America. They feel that this approach should be promoted in African countries to reduce farmers' dependence on governments.

Finally, the study tour enabled the participants to assess the importance of South-to-South exchange in the struggle against poverty and underdevelopment. A package of recommendations has been developed in preparation for followup actions. In the short term, the participants highly recommend the organization in a sub-Saharan country of a workshop to promote rural development concepts and strategies observed in Central America.

At the end of the tour, the group came away with the understanding that the people of the South are slowly but surely beginning to realize that the future lies in their own hands. The participants committed themselves to speed up this promising evolution in their own environments.

Using Fertilizer to Generate Employment in West Africa

Contrary to the often-reported seasonal-labor bottlenecks in sub-Saharan Africa, the World Bank reports that unemployment and underemployment, particularly among the youth in rural sub-Saharan Africa, are increasing. The desire for a better life usually tends to attract most of these unemployed young men and women to the cities and other urban centers where employment opportunities are not better. Conclusions drawn from an impact study on the socioeconomics of fertilizer management strategies at village communities in the Sahel region of Niger suggest that fertilizer use could be part of the solution to the seemingly intractable problem of rural unemployment in West Africa. In addition to sharp increases in crop yields and farm incomes, the study revealed the following:

- Proper use and management of fertilizer have significant impacts on the use of household and hired labor for agricultural production activities. Farmers who used fertilizers required about four times as many workdays/ha (16.9) of hired labor than did nonusers (4.2) to produce 1 ha of crops. The same applies to the use of household labor in that farmers who used fertilizers required about 50% more workdays/ha of household labor than did nonusers for farm activities. An important socioeconomic aspect in countries that have large families is that fertilizer use increases on-farm employment.

- By extrapolation, the estimated 604 ha of cropland in the study village that received fertilizers during the survey year may have provided employment for the equivalent of 10,207.6 workdays. At the going wage rate of CFA franc 500/day (US $2.00), this translates into an income of CFA franc 5,103,800 (US $20,415.2) to the unemployed and underemployed in the village and its environs. Considering the fact that climatic conditions in the Sahel limit farm activities to only 90-120 days in the year, fertilizer use in the study village may have created jobs for about 90-100 young men and women.

- Although the increased use of labor attributable to fertilizer use may represent an additional cost to some farmers, in situations of growing unemployment and underemployment, increased employment is in fact socially and economically beneficial to the entire village community.

- The use of organic matter with mineral fertilizers proved profitable and should be developed when manure is available to save on monetary input and increase farm employment.

- Average wages are higher in Ghana than in Niger and Togo, but traditional cereals cropped in the latter two countries permit the use of more workdays than is the case with maize in Ghana (Figure 15).

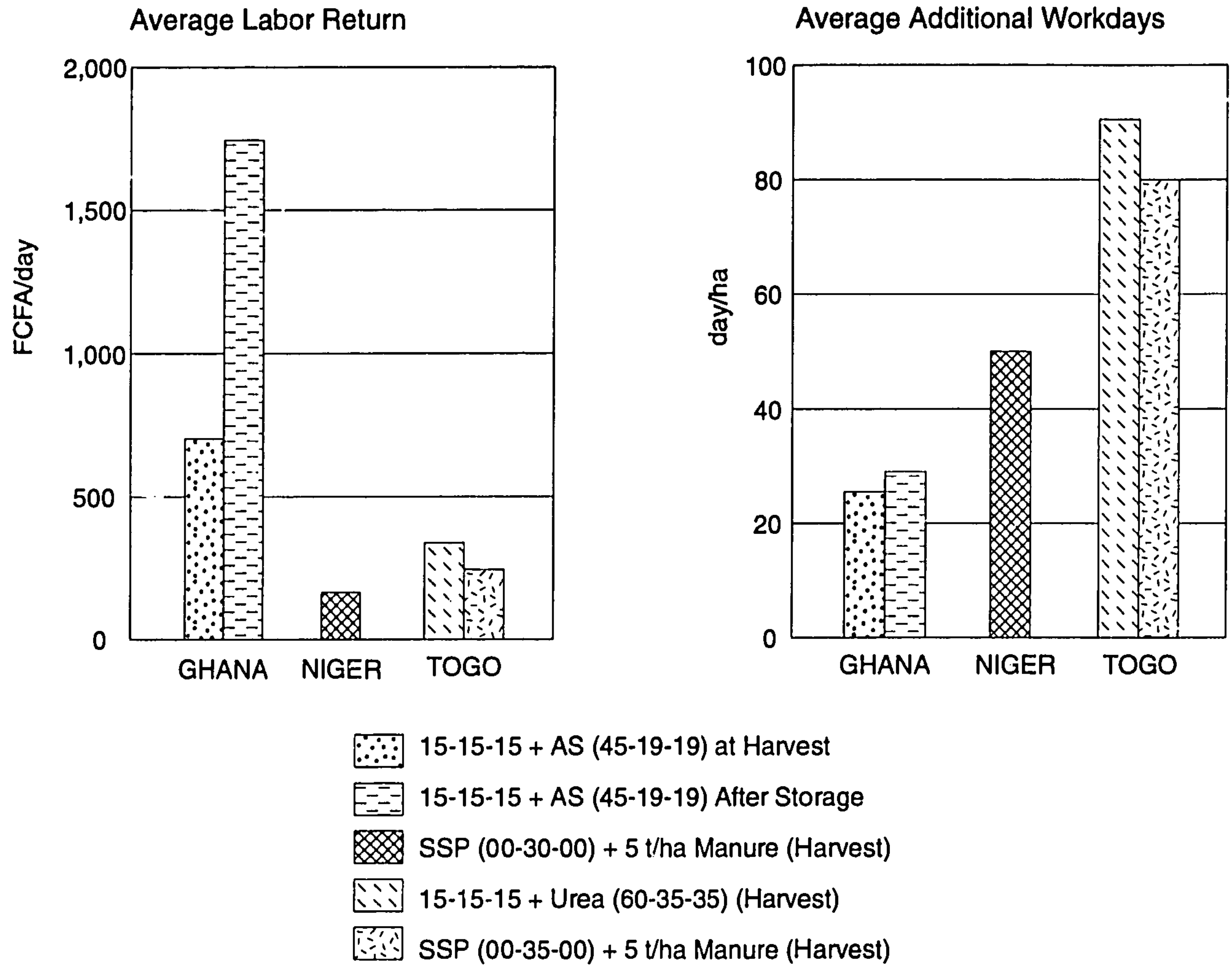


Figure 15. Increased Employment Due to Fertilizer Use.

50 Hurt Plaza
Suite 1700
Atlanta, GA 30303

Telephone 404 658 1800
Facsimile 404 658 8899

Price Waterhouse

REPORT OF INDEPENDENT ACCOUNTANTS

March 11, 1994

To the Board of Directors of
International Fertilizer Development Center

In our opinion, the accompanying balance sheets and the related statements of revenue, expenses and changes in fund balances, of functional expenses and of cash flows present fairly, in all material respects, the financial position of International Fertilizer Development Center at December 31, 1993 and 1992 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 AT DECEMBER 31, 1993 AND 1992

	1993	1992
CURRENT FUND		
Cash and cash equivalents	$ 2,896,460	$ 2,205,903
Short-term investments	0	98,000
Amounts receivable from donors (Notes 1 and 2)	6,427,078	5,538,553
Other accounts receivable	1,274,024	2,230,945
Advances to employees	86,192	141,683
Supplies inventory (Note 1)	144,408	105,995
Prepaid expenses	160,407	29,599
	$ 10,988,569	$ 10,350,678
NONCURRENT FUND		
Amounts receivable from donors - restricted (Notes 1 and 2)	$ 0	$ 2,973,023
BUILDINGS AND EQUIPMENT FUND (Note 1)		
Buildings	$ 5,976,400	$ 5,976,400
Equipment	5,150,179	5,140,043
	11,126,579	11,116,443
Less - Accumulated depreciation	(7,515,344)	(7,308,690)
	3,611,235	$ 3,807,753

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

INTERNATIONAL FERTILIZER DEVELOPMENT CENTER

BALANCE SHEETS - LIABILITIES AND FUND BALANCES AT DECEMBER 31, 1993 AND 1992

	December 31, 1993	December 31, 1992
CURRENT FUND		
Accounts payable	$ 410,949	$ 1,025,359
Accrued annual and sick leave (Note 1)	1,797,146	1,722,610
Deferred revenue (Notes 1 and 2)	7,624,887	6,486,599
Total liabilities and deferred revenue	9,832,982	9,234,568
Fund balance	1,155,587	1,116,110
	$ 10,988,569	$ 10,350,678
NONCURRENT FUND		
Deferred revenue - restricted (Notes 1 and 2)	$ 0	$ 2,973,023
BUILDINGS AND EQUIPMENT FUND (Note 1)		
Contract retainage	$ 421	$ 421
Lease obligation (Note 3)	0	0
	421	421
Fund balance	3,610,814	3,807,332
	$ 3,611,235	$ 3,807,753

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

INTERNATIONAL FERTILIZER DEVELOPMENT CENTER

STATEMENTS OF REVENUE, EXPENSES AND CHANGES IN FUND BALANCES FOR THE YEARS ENDED DECEMBER 31, 1993 AND 1992

	Current Fund		Buildings and Equipment Fund		Total All Funds	
	1993	1992	1993	1992	1993	1992
Revenue						
Grants (Note 2)	$ 18,488,621	$ 19,445,643	$ 0	$ 0	$ 18,488,621	$ 19,445,643
Recoverable project costs	4,687,985	4,866,653	0	0	4,687,985	4,866,653
Other	228,806	417,764	0	0	228,806	417,764
Total revenue	23,405,412	24,730,060	0	0	23,405,412	24,730,060
Expenses						
Field programs	4,710,206	16,517,826	58,625	73,276	4,768,831	16,591,102
Research	2,491,726	2,902,160	117,834	117,543	2,609,560	3,019,703
Outreach	13,263,463	2,452,083	132,016	121,377	13,395,479	2,573,460
General and administrative	2,713,355	2,687,189	75,228	74,886	2,788,583	2,762,075
Total expenses	23,178,750	24,559,258	383,703	387,082	23,562,453	24,946,340
Excess (deficiency) of revenue over expense	226,662	170,802	(383,703)	(387,082)	$ (157,041)	$ (216,280)
Other changes in fund balances						
Transfers from current fund for equipment acquisitions and capital lease payments	(187,185)	(108,528)	187,185	108,528		
Fund balances, beginning of period	1,116,110	1,053,836	3,807,332	4,085,886		
Fund balances, end of period	$ 1,155,587	$ 1,116,110	$ 3,610,814	$ 3,807,332		

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, 1993 AND 1992

	Field Programs		Research		Outreach		Administrative		Total Expenses	
	1993	1992	1993	1992	1993	1992	1993	1992	1993	1992
Personnel compensation (Note 4)	$ 2,145,456	$ 2,400,617	$ 1,220,393	$ 1,373,433	$ 1,803,911	$ 1,215,380	$ 1,366,079	$ 1,245,209	$ 6,535,839	$ 6,234,639
Personnel benefits (Note 4)	497,790	626,684	415,980	474,032	507,407	306,905	386,457	410,523	1,807,634	1,818,144
Travel and transportation	842,749	4,810,557	192,992	305,938	3,568,859	399,210	210,260	247,663	4,814,860	5,763,368
Occupancy	41,144	40,695	202,836	182,537	208,780	182,537	202,837	182,537	655,597	588,306
Telephone and telegraph	179,837	119,056	43,704	31,809	87,891	51,374	40,274	32,708	351,706	234,947
Rental of equipment	177,731	244,363	46,236	66,085	134,634	1,956	20,120	1,459	378,721	313,863
Contractual research and development	104,270	73,106	91,961	143,307	12,100	0	0	0	208,331	216,413
Other contractual services	313,896	898,921	70,244	104,298	653,142	98,336	293,788	203,209	1,331,070	1,305,214
Institute of International Education fee	0	0	0	0	0	0	0	91,510	0	91,510
Materials and supplies	351,128	7,189,928	174,976	182,106	6,206,341	145,166	160,701	234,709	6,893,146	7,751,909
Postage	26,589	30,655	13,022	11,722	26,907	22,927	12,874	11,144	79,392	76,448
Insurance	29,616	83,244	19,332	26,893	53,491	30,984	19,965	26,894	122,404	168,015
Miscellaneous	0	0	50	0	0	(2,692)	0	(376)	50	(3,518)
Total expenses before depreciation	4,710,206	16,517,826	2,491,726	2,902,160	13,263,463	2,452,083	2,713,355	2,687,189	23,178,750	24,559,258
Depreciation of buildings and equipment	57,593	73,726	114,831	115,566	128,881	121,377	69,865	74,886	371,170	385,555
Loss on disposal of equipment	1,032	(450)	3,003	1,977	3,135	0	5,363	0	12,533	1,527
	58,625	73,276	117,834	117,543	132,016	121,377	75,228	74,886	383,703	387,082
Total expenses	$ 4,768,831	$ 16,591,102	$ 2,609,560	$ 3,019,703	$ 13,395,479	$ 2,573,460	$ 2,788,583	$ 2,762,075	$ 23,562,453	$ 24,946,340

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, 1993 AND 1992

	1993	1992
Cash flows from operating activities		
Deficiency of revenue over expenses	$ (157,041)	$ (216,280)
Adjustments to reconcile deficiency of revenue over expenses to net cash provided by operating activities		
Depreciation	371,220	385,555
Loss on disposal or donation of equipment	12,483	1,527
Changes in assets and liabilities		
Decrease (increase) in short-term investment	98,000	(98,000)
Decrease in receivables from donors	2,084,498	2,772,513
Decrease (increase) in advances to employees	55,491	(38,346)
Decrease (increase) in other accounts receivable	956,921	(916,138)
(Increase) decrease in prepaid expenses	(130,808)	375,830
(Increase) decrease in supplies inventory	(38,413)	69,805
(Decrease) increase in accounts payable and accrued annual and sick leave	(539,874)	509,489
(Decrease) in deferred revenue	(1,834,735)	(2,837,386)
Net cash provided by operating activities	877,742	8,569
Cash flows from investing activities		
Capital expenditures	(187,185)	(86,835)
Net cash used in investing activities	(187,185)	(86,835)
Cash flows from financing activities		
Principal payments under capital lease obligation	0	(21,693)
Net cash used in financing activities	0	(21,693)
Increase (decrease) in cash and cash equivalents	690,557	(99,959)
Beginning cash and cash equivalents	2,205,903	2,305,862
Ending cash and cash equivalents	$ 2,896,460	$ 2,205,903

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

INTERNATIONAL FERTILIZER DEVELOPMENT CENTER

NOTES TO FINANCIAL STATEMENTS

1. ORGANIZATION AND ACCOUNTING POLICIES

International Fertilizer Development Center (IFDC) is a not-for-profit 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 accrual basis of accounting has been used in these financial statements. To ensure observance of limitations and restrictions placed on the use of resources available to IFDC, the accounts of IFDC are maintained in accordance with the principles of fund accounting. The following is a summary of significant accounting policies:

A. Grants are recorded as receivable in full at the date of the grant with revenue recognition deferred until corresponding expenses have been incurred. Revenue from recoverable project costs is recognized as the related project costs are incurred.

   Grant 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.

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

C. 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.

D. Annual leave and sick leave accrue at the monthly rate of 16 hours and 8 hours, respectively. Unused annual leave transfers to sick leave until the employee's sick leave balance equals 1,200 hours. Thereafter, unused annual leave is forfeited.

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

F. 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.

G. Investments are recorded at the lower of cost or market value.

H. The costs of providing the various programs and other activities have been summarized on a functional basis in the Statements of Functional Expenses. Accordingly, certain costs have been allocated among the programs and supporting services that benefit from such costs as follows:

Field Programs: Consisting of the Africa and the Asia Divisions, which are located in their respective regions with each specializing in problems indigenous to these regions.

Research: Activities involve assisting in identifying and alleviating soil fertility and plant nutrient management constraints to agricultural productivity in less developed countries in an economic, equitable, sustainable and environmentally appropriate manner.

Outreach: Responsible for assisting in the transfer of technology to less developed countries through information development, collection, analysis and reporting and human resource development.

Administrative: Responsible for the overall operation of IFDC, including setting priorities and policies, managing all fiscal activities, implementing new programs and supplying support services to assist all of IFDC.

2. GRANTS

Grants are summarized as follows:

	Year ended December 31,			
	1993		1992	
	Restricted	Unrestricted	Restricted	Unrestricted
Grants received				
United States Agency for International Development (AID)	$ 15,365,921	$ 2,500,000	$ 13,093,334	$ 2,500,000
United Nations Development Program (UNDP)				
International Development Research Centre (IDRC)				
Rockefeller Foundation				
Directoraat Generalaal voor Internationale Samenwerking (Netherlands) (DGIS)				
World Bank		860,000		770,000
Centre de Cooperation Internationale en Recherche Agronomique pour le Developpment (CIRAD)	83,552			
	15,449,473	3,360,000	13,093,334	3,270,000
Amounts deferred during prior year	7,297,347	1,880,000	10,018,832	2,240,824
	22,746,820	5,240,000	23,112,166	5,510,824
Less - amounts deferred to future periods	(5,875,054)	(1,684,428)	(7,297,347)	(1,880,000)
Other adjustments	(1,938,717)			
Revenue recognized in current period	$ 14,933,049	3,555,572	$ 15,814,819	3,630,824
		14,933,049		15,814,819
Total restricted and unrestricted		$ 18,488,621		$ 19,445,643

Other adjustments consist primarily of the write-off of a previously recorded deferred revenue amount related to a World Bank grant for which funding was cancelled during 1993.

In addition to grant amounts deferred to future years, as indicated above, deferred revenue at December 31, 1993 and 1992 includes $65,405 and $282,275, respectively, of cash collected on reimbursable cost projects for which revenue has not been recognized.

During 1993, IFDC received restricted grants from AID. Approximately $15,352,000 of such grants related to feed procurement and technical assistance in Eastern Europe.

During 1993 and 1992, IFDC received core (unrestricted) funding from AID in the amount of $2.5 million per year, which represents approximately 75% of IFDC's core funding.

During 1992, IFDC received restricted grants from AID. Approximately $11,441,000 of such grants related to fertilizer and equipment procurement and technical assistance in Eastern Europe.

Receivables from donors at December 31, 1993 and 1992 are summarized as follows:

	1993		1992	
	Restricted	Unrestricted	Restricted	Unrestricted
AID	$ 4,503,906	$ 842,428	$ 1,341,158	$ 1,160,000
UNDP			1,013,228	
IDRC	104,484		185,405	
DGIS	976,260		1,854,035	
World Bank			2,957,750	
	5,584,650	842,428	7,351,576	1,160,000
Less - Noncurrent portion			2,973,023	
	$ 5,584,650	842,428	$ 4,378,553	1,160,000
		5,584,650		4,378,553
Total restricted and unrestricted		$ 6,427,078		$ 5,538,553

3. CAPITALIZED LEASE OBLIGATIONS

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

	December 31, 1993	December 31, 1992
Office Equipment	$ 130,672	$ 130,672
Less: Accumulated depreciation	62,449	51,560
	$ 68,223	$ 79,112

4. INSTITUTE OF INTERNATIONAL EDUCATION

In 1992, IFDC had a contract with the Institute of International Education (IIE) whereby all payroll and administrative functions were performed by IIE; IFDC made advances monthly to fund salaries, employment taxes and fringe benefits. As of January 1, 1993, IFDC ended its relationship with IIE.

International Fertilizer Development Center 1993 Projects

Project/Purpose	Funding Source	U.S. $ Dollars	Duration
Global			
Unrestricted *Research and Development Grant:* To assist farmers in developing countries to meet the plant nutrient demands of their crops, increase farm income, promote national food security with sustainable agriculture and protect the environment from agricultural degradation and pollution from fertilizer production and use.	USAID	2,500,000	annually
	World Bank	860,000	annually
Restricted Development and promotion of sound strategies to produce and use fertilizers to sustain agriculture while at the same time affording protection to the environment.	UNDP/ World Bank	3,589,800	1990-93
Fertilizer Manual Technology input toward the development of the Third Edition of the Fertilizer Manual.	UNIDO	46,300	1993/94
Africa			
Collection and Dissemination of Fertilizer Information—Phase II This project aims at improving the collection, analysis, and dissemination of Fertilizer Trade and Marketing Information in Sub-Saharan Africa with emphasis on West Africa.	DGIS	2,838,000	1991-94
Fertilizer Investment for Soil Fertility Restoration To identify the constraints to fertilizer adoption in various 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.	CIRAD	60,000	annually
		150,000	in-kind annually

Project/Purpose	Funding Source	U.S. $ Dollars	Duration
Fertilizers and Sustainable Agriculture Identifying the role and maximizing the benefits of fertilizer use to the farmer to help meet crop nutrient demands.	UNDP	2,300,000	1990-94
Fertilizer and Transport Sector Assessment—Ethiopia A study to obtain a more in-depth understanding of issues that affect the further liberalization and efficiency of the fertilizer and transport sectors in relation to the successful development and implementation of a competitive markets program.	USAID	136,800	1993
Policy Reform—Egypt A study to assess the impact of policy reform on marketing, pricing, and use of fertilizers and agricultural chemicals.	USAID	198,210	1993
Studies and Experimental Assessment on NPK (Plus) Conduct an opportunity study to assess the potential to produce and consume NPK (Plus) fertilizers in Egypt; carry out technical assistance and training to establish a data base and investment analysis unit within EFDC; provide assistance to procure, assemble, and make operational a multipurpose pilot plant.	UNIDO	935,000	1989-94
Study Tour to Latin America To improve African farmers' ability to produce food by enabling African agricultural professionals to observe alternative extension delivery methods.	W. K. Kellogg	84,000	1993
Training Program for Fertilizer and Agri-Input Dealers in Egypt To initiate an in-country training program principally for Egypt's private sector dealers and agricultural cooperatives by upgrading their knowledge and skills so as to better service the farmer's agriculture-related needs in a competitive marketplace.	USAID	155,000	1993
Asia			
Fertilizer Distribution and Marketing Consultancy Services to the Government of Bangladesh To assist the Ministry of Agriculture (MOA) to improve fertilizer marketing by incorporating private sector concepts and resources.	Govt. of Bangladesh	9,077,000	1992-94

Project/Purpose	Funding Source	U.S. $ Dollars	Duration
Fertilizer Marketing Sector Study for Indonesia To appraise the present fertilizer marketing system in Indonesia for determining inefficiencies and constraints as well as making the appropriate recommendations for improvement.	Ministry of Agriculture	379,300	1992/93
Design of the Agribusiness and Technology Development Project To increase private sector investment in agricultural input and technology production and marketing in Bangladesh.	USAID	284,000	1992-94
Eastern Europe			
Short-Term Technical Assistance to Albania To assist the Government of Albania to implement an emergency program of fertilizer imports and distribution by open market auction.	USAID	1,960,000	1992/93
Fertilizer Importation Program for Albania To assist the Government of Albania in the importation of fertilizer for use in Albania.	USAID	8,700,000	1992/93
Vehicle Transportation Program for Albania To assist the Government of Albania to remove immediate in-country constraints to transportation of imported fertilizer.	USAID	2,250,000	1992/93
Long-Term Technical Assistance to Albania To assist the Government of Albania in restructuring the fertilizer subsector.	USAID	4,316,520	1993/94
Short-Term Technical Assistance to Romania To design a Commodities Importation Program for the importation and open market auction of high protein animal feed supplement.	USAID	271,000	1992/93
Feed Supplement Importation Program for Romania To assist the Government of Romania in importation of high protein-based feed supplement for use in Romania.	USAID	8,500,000	1993/94
Long-Term Technical Assistance to Romania To assist the Government of Romania in a protein-based animal feed supplement importation program.	USAID	2,505,100	1993/94

Project/Purpose	Funding Source	U.S. $ Dollars	Duration
Latin America			
Farm-Level Modeling for Natural Resource Use Planning: A Case Study in Uruguay To assist and train Uruguayan scientists in the development of a national capability for effective resource use planning.	Rockefeller	100,000	1993-95
Technical Assistance to INTEVEP To perform continuous MCP-WPA production.	INTEVEP	80,000	1993
Technical Assistance to PEQUIVEN To assist PEQUIVEN in developing a business plan to allow fertilizer operations to be competitive in a free market economy.	PEQUIVEN	400,000	1993/94

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[1]Left during 1993.
[2]Retired during 1993.

a. Seconded to IFDC by Centre de Coopération Internationale en Recherche Agronomique pour le Développement.
b. Seconded to IFDC by Directoraat Generaal Voor Internationale Samenwerking (Netherlands).

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Acronyms and Abbreviations

AAIC	Agricultural Assessment International Corporation
ABOCOL	Abonos Colombianos S.A.
AFADA	Albanian Fertilizer and Agricultural Inputs Dealers Association
ALES	Automated Land Evaluation System
ASF	Area Sampling Frame
CIAT	Centro Internacional de Agricultura Tropical
CMDT	Compagnie Malienne pour le Developpement des Textiles
CORPOICA	Corporación Centro de Investigaciones Agropecuarias
DGIS	Directoraat Generaal voor Internationale Samenwerking
DSSAT	Decision Support System for Agrotechnology Transfer
EFDC	Egyptian Fertilizer Development Center
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuaria
FADINAP	Fertilizer Advisory Development and Information Network for Asia and the Pacific
FAO	Food and Agriculture Organization of the United Nations
FERTICA	Fertilizantes de Centro America S.A.
FINTRA	Fiduciaria de Inversiones Transitorias
FNFF	Fier Nitrogen Fertilizer Factory
FUCREA	Federación Uruguaya de Grupos CREA
GIS	Geographic Information System
HYVs	High-Yielding Varieties
IARCs	International Agricultural Research Centers
IBSNAT	International Benchmark Sites Network for Agrotechnology Transfer
IDRC	International Development Research Centre
IFDC	International Fertilizer Development Center
INIA	Instituto Nacional de Investigación Agropecuaria
IRRI	International Rice Research Institute
ISSER	Institute of Statistical, Social, and Economic Research
MOAF	Ministry of Agriculture and Food
NARES	National Agricultural Research and Extension Systems
NARS	National Agricultural Research Systems
NGOs	Nongovernmental Organizations
PAPR	Partially Acidulated Phosphate Rock
PBDAC	Principal Bank for Development and Agricultural Credit
PDVSA	Petroleos de Venezuela S.A.
PEQUIVEN	Petroquimica de Venezuela
SCAER	Société de Credit Agricole et Equipement Rural
SFRP	Soil Fertility Restoration Project
TSP	Triple Superphosphate
UNDP	United Nations Development Programme
USAID	U.S. Agency for International Development
USG	Urea Supergranules
UNIDO	United Nations Industrial Development Organization
WAFMEN	West African Fertilizer Management and Evaluation Network

IFDC's Offices

(as of July 1994)

Headquarters

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

Other IFDC Offices

Africa

IFDC-Africa
B.P. 4483
Lomé
TOGO
Telephone: (228)217971*
Telex: 5416 CIFDC TG
Telefax: (228)217817

IFDC/ICRISAT Sahelian Center
BP 12404
Niamey
NIGER
Cable: ICRISAT, Niamey
Telephone: (227)722529/722725/723697*
Telex: 5406 NI
Telefax: (227)734329

Asia

IFDC/Dhaka
GPO 3044
Dhaka
BANGLADESH
Telephone: (880+2)885626 or 885620
Telefax: (880+2)883079

IFDC/Asia Division
House No. 121
Block-F, Road No. 1
Banani Model Town
Dhaka
BANGLADESH
Telephone: (880+2)886109 or 605460
Telefax: (880+2)883102

IFDC/IRRI
P.O. Box 933
Manila
PHILIPPINES
Telephone: (63+2)8181926
Telex: ITT 45365 RICE INST PM
Telefax: (63+2)8178470 or (63+2)8182087

Eastern Europe

IFDC/Albania
The Enterprise of Administrative and Public Services Building, 3rd Floor
Rruga "Kongresi i Permetit"
Tirana
ALBANIA
Office Telephone/Fax: (355+42) 23633
[redacted]

IFDC/Romania
c/o DHL Office
Bucharest
ROMANIA
Telephone: (40+1)3111286/6504672
Telefax: (40+1)3111286/6504672

Latin America

IFDC/CIAT
Apartado Aéreo 6713
Cali
COLOMBIA
Telephone: (57+2)4450-000
Telex: 05769 CIAT CO.ITT
Telefax: (57+2)4450-273

IFDC/UNDP Project
J. Barrios Amorin 870 Piso 3
Montevideo 11200
URUGUAY
Telephone: (598+2)423357/58/59
Telefax: (598+2)423360

IFDC/PEQUIVEN
Filial de Petróleos de Venezuela
Moron-Edo. Carabobo
VENEZUELA
Telephone: (58+42)609315
Telefax: (58+42)609336

*Please note: Niger and Togo do not have city codes.

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

Telephone: 205-381-6600
Telex: TWX-810-731-3970 IFDEC MCHL
Telefax: 205-381-7408
E-Mail: IFDC.GENERAL @ cgnet.com

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