International Fertilizer Development Center
Annual Report 1994

"IFDC's Impact in the Global Village"

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Message From the President and Chief Executive Officer

This edition of our annual report focuses on IFDC's impact in the global village. Throughout the report information boxes contain examples of the impact of the efforts being made by our staff around the globe in the developing countries and the new democracies in eastern and central Europe. IFDC is tackling some of the most important challenges related to feeding the burgeoning world population through the improvement of soil fertility, better management of nutrients, and policy reform to establish open and competitive markets and efficient economic systems.

The United Nations estimates that more than 700 million people in the developing world do not have access to enough food to live healthy and productive lives. An estimated 13-18 million people, mostly children, die from hunger, malnutrition, and poverty-related causes each year – that is about 40,000 people per day or 1,700 people per hour. According to the United Nations' projections, the number of people living in absolute poverty will increase from 1.2 billion today to 1.5 billion by 2025. To solve these seemingly insurmountable problems, the United Nations forecasts that agricultural output must be tripled and people must have the income to buy it.

Sustainable food security cannot be achieved without the benefits of intensified agriculture – the key to alleviating poverty. The adoption of improved technology and the application of modern inputs of agriculture can boost significantly food supply in Africa, for example, where fertilizer use is only a quarter of average use levels in India. As a case in point, thirty farmers who participated in an IFDC project in sub-Saharan Africa increased

their millet yields by 250% by applying various forms of phosphate fertilizers to their crops. With increasingly limited land under cultivation, the only way to produce enough food for the growing number of people is to boost yields through the use of organic and inorganic fertilizers. In fact, Dr. Norman Borlaug, 1970 Nobel Peace Prize recipient, has said that "the use of chemical fertilizer must be expanded two- to threefold to maintain soil fertility and productivity in the developing countries over the next 20 years if the world is to feed itself." By that time the United Nations estimates that world population will exceed 8 billion, 45% greater than that of today. Almost 7 billion of that future population will be living in the developing countries, and even though measures to control population are vital, the production side of the equation is as important as ever.

By applying innovative agricultural technologies in an agribusiness setting, IFDC is laying the groundwork for the alleviation of poverty in countries such as Albania, Bangladesh, and Romania. In Albania and Bangladesh IFDC has effectively linked agricultural production with economic development through the design and implementation of economic policies that promote the free market system and lead to economic efficiency, increased employment, and overall economic growth. IFDC's work in Asia, Africa, Latin America, and the new democracies of eastern and central Europe promotes the implementation of market principles that result in increases in both agricultural production and economic development. In Latin America, for example, IFDC is assisting a Venezuelan fertilizer producer as it makes the transition to the free market system and realizes increased efficiencies and savings.

The future will undoubtedly hold new challenges that will require vision and a renewed determination to measure up to the tasks. With the help of our supporters, partners, and collaborators and the people of the developing countries, hopefully we shall achieve even greater progress and accomplishments in the future.

Amit H. Roy

Guest Essay by Dr. Michel Griffon — Toward a Doubly Green Revolution

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The retrospective analysis of the success and limitations of the "Green Revolution" strategy has recently led a group of scientists to recommend a new strategy coined "Doubly Green Revolution." This strategy gains its momentum and rationale from the Green Revolution; on the other hand, it minimizes potential drawbacks related to social inequity and environmental damage.

The "Doubly Green Revolution" calls for a new approach both to prioritize research programs and to develop a multidisciplinary and multisectorial effort in the implementation of these programs by the main stakeholders, including farmers, agriculturists, environmentalists, agribusiness partners, policymakers and funding organizations. Through its multidisciplinary and integrated scientific approach to the development of appropriate systems of procurement, distribution and use of plant nutrients ("from mine to farm, through markets"), IFDC contributes significantly to the coordinated research thrust and the capacity building effort both urgently needed to promote the new "Doubly Green Revolution" (DGR) in developing countries.

Introduction and Background

According to the Food and Agriculture Organization of the United Nations (FAO), poverty and undernourishment currently affect about 700 million people. The challenge of doubling the world food supply in the next 30 years is formidable.

Although this challenge calls for fundamental changes in the global economy, national policy, and individual behavior, it is certain that agriculture and rural development can make a significant contribution not only to the global food security issue but also to two other global issues – poverty and inequity reduction and sustainable natural resources management. The most pressing solutions have to be implemented in the poorest countries, where (1) agriculture is still the dominant sector in terms of employment, gross national product (GNP), and exports, (2) farmers are the principal users of fresh water and land, and (3) land and soil degradation is a growing threat hampering agricultural intensification in these poor countries. Global sustainable development will never be achieved without ensuring in an environmentally benign way

the maintenance and, where appropriate, the enhancement of land productivity.

Two primary components of sustainable improvement in agriculture can be identified. First, dissemination of information to farmers is needed to promote improved practices for sustainable land use in agriculture and for opportunities of diversification. This is the traditional role of research and extension organizations. Of equal importance is the identification and implementation of a favorable socioeconomic and policy environment for agricultural producers, including infrastructure, transport and market facilities, easy access to credit, fair price policy for inputs and outputs, and land use security. In addition to weather-related risks and uncertainty, agriculture in many developing countries is also plagued by inappropriate land use practices, local market failures and distortions, and by institutional failures. As a consequence, most farmers have very high discount rates, and it is most unlikely that farmers will adopt improved practices on the basis of improved information alone, especially in its research dimension. Sustainable improvement in agriculture calls for a better integration of these two components and their adaptation to specific and local problems. This is indeed a new domain to be developed by research institutions.

Recently a task force of the Consultative Group on International Agricultural Research (CGIAR) concluded that a new strategy of agricultural development should be developed to find and implement the appropriate solutions in developing countries. This strategy was named the "Doubly Green Revolution," both to show the continuity with the well-known Green Revolution, which has dramatically increased food production, and to clearly state that this new strategy should place equal emphasis on the maintenance of a "green" and economically sound environment favorable to human development. The DGR calls for a challenging effort among the world international, regional, and national scientific community to reach the same momentum previously reached by the Green Revolution a few decades ago. New research disciplines and themes must be strengthened particularly in the field of agroecology and environmental economics. More importantly, ways of doing research must be highly participatory and involve all the stakeholders of rural development.

From this perspective, IFDC can be seen as one of the significant scientific contributors to the development of DGR, with regard to its domain of participatory research on a holistic approach to plant nutrient management and the comprehensive and multidisciplinary assessment of all aspects of plant nutrient supply and use ("from mine to farm through markets"). In addition, IFDC's role in the DGR has been established through its experience in contributing to project implementation and in strengthening local public and private agricultural organizations through intense training activities.

Before going into more detail about the need for research and development to promote and foster the DGR in developing countries, I will briefly summarize the rationale for the DGR by presenting a short analysis of the past successes and limitations of the Green Revolution.

The Green Revolution: Successes and Limitations

After the Second World War Asia was the most densely populated continent and was undergoing rapid demographic expansion. An unprecedented rise of food requirements was experienced throughout this continent; furthermore, the risk of famine and poverty fueled movements of social unrest. The Green Revolution, a coherent response to these problems, was based on major research findings and extension of the resulting intensive technologies, such as high-yielding varieties of rice and wheat, increased use of inorganic fertilizer, better soil and water management under irrigation conditions, and improved pest and disease control methods. In the 1960s, India had a population of 500 million and was dependent on food imports. Today, India no longer relies on imports to feed one billion people. Elsewhere in the world, the Green

Revolution has been successful mostly in Asian countries where irrigation is currently used but also in Latin American countries such as Mexico and in a few African countries such as Zimbabwe.

However, the Green Revolution has been increasingly criticized and is no longer viewed as the universal model to be applied to address internationally the issues of food production and poverty alleviation. The Green Revolution has never been broadly adopted by subsistence farmers in most African countries and, when adopted in some Asian and Latin American countries, new socioeconomic and lately environmental problems have arisen.

First, it is obvious that the Green Revolution requires more than the extension of new technologies. In Asia, substantial changes in agricultural policy have been key to success. These changes included levels of relative prices favorable to food production, stable agricultural prices, more secure access to food guaranteed by plentiful public stocks, input subsidies, and easy access to credit. It was also observed that most Asian countries, in comparison with Africa were open to the establishment of market economies sooner, because of better transport and communication networks and more integrated agricultural sectors. Asia has traditionally benefited from stable institutions, both at national and district levels; whereas, in most African countries, centrally organized states have a short history. Currently these states are facing critical financial situations and, thus, huge difficulties in implementing the required changes in agricultural policies.

The Green Revolution has been criticized lately because it is usually adopted and profitable under irrigation conditions and by those farmers who have a comparative advantage as far as land, capital, and access to credit and markets are concerned. Extensive surveys conducted in Asian countries show that the Green Revolution benefited all types of farmers but did not change inequity patterns.

More recently, another limitation has been identified. Concern is mounting as to the long-term sustainability of the biophysical components of the environment under intensive farming conditions. Land degradation, or particularly soil fertility decline, is an increasingly significant limitation of agricultural productivity. Such a phenomenon is not only reported in poorly endowed areas, such as sub-Saharan African regions, but also in highly productive areas where increased crop productivity caused by the "Green Revolution" is now plateauing, if not decreasing as currently reported in the Indo-Gangetic Plain. Other causes, such as unfavorable trends in the price of rice, are likely contributing to stagnating yields, but it would be foolish to ignore evidence of other practices, such as unbalanced fertilization or misuse of irrigation water, which may cause environmental damage.

Finally, the primary focus of the DGR is a "no-regret" strategy, i.e., a strategy that aims to keep the risk factor within acceptable limits by adopting measures that will remain useful in all possible future scenarios. The DGR aims at poverty alleviation, increased food production, decreased social inequity, alleviation of agriculture's negative effects, and enhancement of its positive impact on the environment.

Intensive agricultural research but, more importantly, new research approaches and methodologies will be required to overcome such a challenge during the next 30 years, that is, to achieve the coexistence between human society's activities and needs with the need for maintaining the capability of managed ecosystems to sustainably support increasing pressures exerted by these societies.

Call for More Integrated and Committed Research

Although some funding agencies are tempted to reduce drastically research funding, a new strategy for sustainable agricultural and rural development, such as DGR, will gain credibility and socioeconomic impact only if a strong and coordinated effort of research is promoted worldwide. However, research organizations are constantly challenged to tailor their activities to the evolving needs of the agriculture sector.

To do "business as usual" will not meet the challenge of the DGR. In this essay, I will only suggest how research on sustainable land use management in developing countries can become more effective, based upon the recent experience of CIRAD and IFDC.

First, from a scientific perspective, research organizations must build close and functional linkages between biophysical science research, such as soil science, agronomy, and research on economics and policy-related matters. This goal will be more easily reached by strengthening our scientific capacity in the fields of agroecology and environmental economics. An agroecological approach to develop an alternative technology such as "Soil-Water Biomass-Nutrient Management" is the most important pillar of the DGR. Profitable and environmentally benign technology has to be designed based upon a better understanding of the complex interactions between the biological, chemical, and physical properties of soil and the impact of cultivation and crop and water management practices on these interactions. In Latin America, particularly in South and Central Brazil, farmer groups supported by local and international research organizations are developing no-tillage systems with very convincing results from an economic and environmental perspective. More scientific data must be gathered on the sustainability of such systems, which is precisely what IFDC scientists are doing in Uruguay and CIRAD scientists have been doing for more than 10 years on research stations and increasingly on farmers' fields.

Environmental economics is also central to the scientific assessment of DGR. The recent pressures to reduce consumption of inorganic fertilizers in developed countries can be very damaging to sustainable land management if they are allowed to impact most developing countries. A special focus should be on the full accounting of benefits and costs of organic and inorganic fertilizer use not only as an intensification input to increase crop productivity and farmers' income but also as an investment to increase or rehabilitate the natural capital in already degraded lands. Of particular relevance is the ongoing World Bank survey on the cost:benefit analysis of the use of indigenous phosphate rock products as a natural capital investment in sub-Saharan Africa. This survey is currently being conducted by a consortium of research and development organizations including IFDC, International Centre for Research in Agroforestry (ICRAF), CIRAD and the Norwegian Centre for International Agricultural Development (NORAGRIC). This study will provide a sound scientific base for investments in soil fertility in Africa by enhancing traditional economics with the valuation of environmental and social benefits and costs (direct or indirect effects) of an investment, such as an increase in carbon sequestration and a reduction of migration rate from rural to urban areas.

Second, research organizations need to develop new linkages, certainly with other research organizations and, more importantly, with all the stakeholders of sustainable agricultural systems. Based upon a fair assessment of the strength and comparative advantage of each organization, linkages must be developed looking for complementarity and synergy. The CGIAR system is putting increasing emphasis on the development of such linkages, based upon a fair share among scientific and managerial responsibilities among partner organizations, including non-governmental organizations (NGOs). Networking as currently practiced by IFDC, for instance, in Africa is a response to this need for linkages among scientific partners. Offering much promise are linkages with not only private organizations involved in agricultural production, such as farmers' cooperatives and local NGOs, but also with agribusinesses. IFDC's linkages with national fertilizer manufacturers from more recently industrialized countries, such as India and Venezuela, provide good illustrations of the fruitfulness of such multisectorial partnerships.

Finally, the ultimate purpose of research organizations committed to developing sustainable agricultural systems is to promote within emerging economies their own capacities to develop and manage such systems. I am pleased to acknowledge IFDC's long-term experience in training and capacity building. Research

organizations need to go beyond this training effort to increase the knowledge base of national scientists from developing countries and also support the decision-making process in these countries. This entails the designing of development scenarios, such as recently developed by the Organization for Economic Cooperation and Development/Comite Inter-Etats pour la Lutte Contre la Secheresse au Sahel(OECD/CILSS) in sub-Saharan Africa with the participation of my Department. It also involves the validation of models to help decisionmakers rationalize regional and national agricultural development. IFDC's recent experience in Albania shows how modeling tools can be used to support the decisionmaking process to develop a national fertilizer subsector based on the assessment of the current food needs and the capacity of soil to meet these needs through better soil and crop management. Other important consequences of the Albania project are the development of a sound credit system, the emergence of private business, and the need for research to improve the data base required for effective modeling and planning. Moreover, IFDC believes that the supporting activities to the development of a marketing economy are important both in planning scientific priorities within the institution and the gaining of increased credibility by IFDC, vis á vis funding agencies, in its ability to foster sustainable agricultural development through a scientific approach.

In conclusion, the DGR is a challenging strategy to reduce poverty, food shortage, and malnutrition and to maintain a healthy and safe environment for our planet's growing population. It is also a challenge to the world's scientific community, which must pave the way toward these objectives. This challenge is faced not only by research organizations, funding and development agencies but also by individual scientists as they balance their activities between the "what" and the "how," that is, between the desirable increase of the knowledge base and their own commitment to the implementation of improved technology to enhance the quality of life of a growing population of world poor.

Nutrient Dynamics Research in Asia and Latin America

In 1994 IFDC continued its nutrient dynamics research as a means of promoting sustainable agriculture. The Center's scientists posted in Asia and Latin America concentrated on developing strategies to help farmers in those regions expand and sustain agricultural production using both inorganic and organic sources of plant nutrients. Their findings are being applied on farms in countries such as Brazil, Colombia, Uruguay, and Vietnam.

Efficiency of urea on broadcast-seeded rice in the Mekong Delta

Direct seeding has been adopted as the most efficient method of planting rice in the Mekong Delta, and urea is the main nitrogen fertilizer applied to this lowland rice area. However, information on the fate of nitrogen in broadcast-seeded flooded rice is limited. With partial funding from the Australian International Development Assistance Bureau (AIDAB), the IFDC-International Rice Research Institute (IRRI) collaborative project has conducted field experiments over the past few years to evaluate the efficiency of applied urea for direct-seeded and transplanted rice in the Mekong River Delta of Southern Vietnam.

Effect of Time of Urea Application on Nitrogen Use Efficiency of Rice in Alluvial Soil

Basal incorporation of urea is one of the strategies to reduce loss of ammonia. However, in the Mekong River Delta many farmers do not basally incorporate nitrogen fertilizer onto the soil sown with direct-seeded rice. Three equal split applications of fertilizer nitrogen are usually broadcast into the floodwater about 10 days after sowing the crop. In some cases, these farmers apply diammonium phosphate (DAP) as a one-third nitrogen basal dose.

Four field trials were conducted with broadcast-seeded flooded rice in the Mekong River Delta during the 1989/90 dry season. Thorough incorporation of urea into the soil without standing water before transplanting theoretically reduces ammonia loss. In this trial, however, basal urea broadcast and incorporated into mud without standing water resulted in no yield advantage over urea broadcast into 5 cm standing water at 10 days after sowing. Therefore, delaying the first urea application until 10 days after sowing as topdress had no adverse effect on the yield of broadcast-seeded rice.

A one-third basal application of DAP plus urea in the other two splits (20, 45 days after sowing) was also tested. When DAP was used as the first nitrogen basal application, yield and yield components were not significantly increased in comparison with urea plus single superphosphate (SSP).

Effect of Seeding Rate and Spacing on Nitrogen Efficiency of Rice in Alluvial and Acid Sulfate Soils in the Mekong River Delta

Rice is planted either by direct seeding or by transplanting in the Mekong River Delta of Southern Vietnam. On alluvial soils, direct seeding is becoming an increasingly popular alternative to transplanting. However, various seeding rates have been used by farmers even in the same area. On acid sulfate soils, transplanting is widely practiced, but plant spacing for this soil has not been established.

Four field experiments were conducted in the 1990/91 dry season in the Mekong River Delta: three sites were broadcast-seeded alluvial soils and another site (acid sulfate soils) was transplanted. Two planting densities and six nitrogen rates were evaluated for these soils.

Grain yield did not differ between two seeding rates of 150 and 250 kg seed/ha at Binhduc and Cailay. In Hoaan, an acid sulfate soil, the yield from 15 x 15 cm was higher than 20 x 20 cm hill spacing. Since Hoaan soil is an acid sulfate soil, plant growth is below normal; thus, closer spacing and planting of several plants per hill are recommended. Hoaan gave the lowest grain yield, seed weight, and percentage of filled spikelets among the sites. In Cantho, the lowest yield was obtained from a high seeding rate primarily because the spikelet number per panicle was lesser than that at a low seeding rate (31 versus 42). In this case the panicle number per square meter (1,088) at a high seeding rate was very much greater than that from other

sites (e.g., Cailay: 672); thus, a lower spikelet number per panicle is expected.

Grain yield responded positively to increased applied nitrogen up to 80 kg nitrogen/ha at Cantho, Binhduc, and Hoaan and up to 120 kg nitrogen/ha for Cailay. Additional application of more than 80 kg nitrogen/ha at Cantho, Binhduc and Hoaan reduced grain yield because of lodging. Because Cantho and Binhduc sites have alluvial soils, they derive their nutrients from yearly river deposits while in Hoaan, high nitrogen interacts with phosphorus since it has an acid sulfate soil.

^{15}N balance in soil plus roots at the Mekong Delta suggests that leaching was not an important loss mechanism in these soils. Nitrogen loss from alluvial soils was 21%-33% of applied urea due to elevated floodwater pH (pH > 8.0) after applying urea. Therefore, nitrogen loss in these sites is presumed to be mainly due to ammonia volatilization. Nitrogen loss from the acid sulfate soil in Hoaan, however, was 5% of applied urea. Therefore, since floodwater pH of this soil after applying urea did not exceed 5.5, ammonia volatilization was not the main pathway of nitrogen loss on this soil.

Effect of Urea Split Application on Nitrogen Use Efficiency of Rice in the Mekong River Delta

Application of urea in three rather than one or two splits may encourage better crop growth and more efficient use of nitrogen with fewer risks of massive nitrogen losses through ammonia volatilization, denitrification, and leaching. Recent research has demonstrated the importance of split application for reducing losses of nitrogen fertilizer and also resulting in higher recovery of nitrogen in the grain and straw. Two field experiments were conducted in the Mekong River Delta with broadcast-seeded rice in the dry season 1991/92 and wet season 1992. The effect of various timings of three or four urea split applications on nitrogen use efficiency was examined.

The total ^{15}N recovery by rice plants was not different among the four urea-nitrogen split application methods. Nitrogen uptake also rarely differed among different split applications. Nitrogen uptake in the dry season was always higher than that in the wet season in every growth stage and in straw and grain.

Grain yield increased significantly in response to applied nitrogen up to 80 kg nitrogen/ha for Binhduc and Cantho in the dry season 1991/92 and wet season 1992. Different split applications of nitrogen at a rate of 80 kg/ha did not significantly increase grain yield. Therefore, there is no advantage in modifying the nitrogen split application from the farmers' present practice of three equal applications at Cantho and Binhduc.

Nutrient management for sustainable agriculture on Latin America's acid soils

The savannas of South America are considered by many to be the last agricultural frontier on the planet and the potential breadbasket of the continent. However, the principal constraints to intensified agricultural production in this ecosystem are high soil acidity and very poor soil fertility. The first of these constraints can be addressed through the judicious use of lime and the development of more acid-soil tolerant crop germplasm, an activity in which several of the international agricultural research centers (IARCs), including the International Center for Tropical Agriculture (CIAT), are actively engaged. The second constraint can only be overcome by the application of fertilizers.

Monocropping coupled with the use of high levels of inputs is increasingly considered to be an unsustainable practice leading to a deterioration of soil physical

IFDC's Impact in Latin America
The Colombian Example

Since its inception IFDC has pioneered work on the characterization and effective use of indigenous agrominerals such as phosphate rock. These technologies have been developed first at Headquarters, subsequently tested at other international agricultural research centers, and eventually passed to institutions at the national level by using regional networks and national programs. On the Latin American continent, IFDC has long been involved in research to find energy-efficient, cost-effective alternatives to the more expensive imported phosphate fertilizers by using natural and altered phosphates from countries like Colombia. As a result of IFDC research and promotion of indigenous resources, 25,000 tonnes of Colombia's Huila phosphate rock (approximately one-seventh of that country's annual consumption of phosphate fertilizers) is now being sold and consumed on Colombian farmers' fields each year. The private sector is now actively involved in the processing and production of phosphate fertilizer based on Huila phosphate rock. By using this indigenous fertilizer, Colombia is realizing an estimated saving in foreign exchange of US $1 million per year. Colombia is only one of the many developing countries that IFDC has helped find ways to use their indigenous phosphate resources as plant nutrients. A few of the other examples include Brazil, India, Mali, Philippines, Tanzania, Venezuela, and Zambia.

properties and escalation of pest problems. The nutrient use efficiency in such systems may also be less than optimal as a result of increased losses through runoff, erosion, leaching, and poor crop rooting characteristics in degraded soils, among other factors. Systems that are more conducive to resource conservation and nutrient cycling are thus essential for the sustainable exploitation of the last frontier.

In 1993 IFDC joined with CIAT and the Colombian national program, Corporación Centro de Investigaciones Agropecuarias (CORPOICA), in establishing a long-term experiment on the Colombian Llanos to investigate sustainable crop rotation and ley farming systems for the acid soil savannas. Several other institutions have since joined to investigate complementary aspects of sustainability not covered by CIAT's and IFDC's expertise. This experiment compares a selection of alternative systems to monocultures, incorporating components that attenuate or reverse their deleterious effects. Components include grain legumes, green manures, and pasture leys in rotations to increase the stability of systems based on annual cereal crops. To varying degrees, these components are expected to expand nutrient cycling and conservation, increase carbon inputs, reduce soil organic matter loss, and maintain the soil physical condition. A principal objective of the project is the development of integrated models that would simulate the effects of system components and management on soil chemical, biological, and physical processes and enable the evaluation and extrapolation in space and time of the effect of components and management deviations on system stability.

The long-term "culticore" experiment, as it is known, has been implemented in two stages. Rice-based systems involving low "fertilizer-rate" levels of lime applications (500 kg/ha) were initiated in 1993 while maize-based systems requiring higher levels of "remedial" lime applications (2 tonnes/ha) commenced in 1994. During the first two years, the experiment has already yielded interesting and useful information. Using fertilizer rates determined in satellite experiments, rice yields of approximately 3-3.5 tonnes/ha were obtained in 1993 and 1994 (Table 1). Yields of rice undersown with pasture were not affected, but the comparatively higher soil fertility resulting from rice fertilization yielded a pasture that could be stocked with animals three months

Table 1. Grain and Dry Matter Production in Monocultures and Rotations in the Long-Term Cropping Systems Trial ("Culticore") at Carimagua

Cultural System	1993 Rice Grain	1993 Rice Dry Matter	1993 Cowpea Grain	1993 Cowpea Dry Matter	1994 Rice	1994 Maize
	(kg/ha)				(kg/ha)	
Monoculture					2,220	
Cereal/grain legume rotation	2,850[a]	12,600[a]	1,130	1,720	3,330	2,330[a]
Cereal/green manure rotation				1,540	3,530	
Agropastoral rotation	3,330	12,500				2,570

a. Treatments harvested as one unit per replicate.

after the rice harvest and would carry them through the dry season with very respectable liveweight gains of 333 grams/day.

The intervening cowpea grain legume and green manure crops, sown in the second cropping season of 1993 after rice, had a significant impact on rice sown in the subsequent 1994 rainy season (Table 1). About 1.5 tonnes/ha of green manure (dry matter basis) incorporated at flowering and 1.7 tonnes/ha of cowpea residues incorporated after harvest in 1993 resulted in more than 1 tonne/ha of additional rice grain yield in 1994. The rice crop during the season was visibly greener in these systems than in the monoculture system, which depended entirely on fertilizer nitrogen applications. While part of the yield gain may be explained by the improved nitrogen economy in the legume rotation treatments, the second season legume crops also had a significant effect on reducing weed infestation in rice the following season.

To define further the effects of the legumes on the nitrogen economy of the rotation systems, the dynamics of mineral nitrogen in the soil profile were followed in the rice monoculture and rice-green manure systems at monthly intervals during the intervening 1993/94 dry season. Ammonium levels in the soil were hardly affected by the green manure which, in contrast, had a marked impact on nitrate concentrations in the profile to 1-meter depth. This effect increased through the dry season such that, by sowing time in early April, it was already apparent that nitrate was moving out of the root zone of the sown rice crop. Cowpea (grain legume) residues also had a significant but lesser impact on profile nitrate concentrations while some nitrate was also derived from decomposing rice straw residues.

Soil profile nitrate levels were again measured after the rice crop harvest in 1994. By this time, most of the residue-derived nitrogen and fertilizer nitrogen (80 kg/ha applied to rice in all systems in three splits), which had not been recovered by the crop, had leached beyond the 60-cm depth. The lower levels of nitrate in the monoculture rice profile compared with the rotations probably reflect the differences in total inputs (which were also reflected in the rice yields). It is probably inevitable that this nitrate, whether derived from fertilizer or residues, will find its way to the ground water. Despite the benefits ascribed to legumes and green manures, therefore, the potential exists for substantial nitrogen losses from rotational systems involving legumes where there is less opportunity to control through management the fate of nitrogen applied by residue incorporation as compared with nitrogen management from mineral fertilizers. These observations demonstrate the need for careful management of both fertilizers and residues to reduce nitrogen leakage from cropping systems and for further research to develop better management strategies of both types of inputs and systems that are more able to use them efficiently.

To improve our knowledge base on the efficient management of inorganic fertilizer inputs, medium-term satellite experiments involving rice-cowpea or maize-soybean rotations continue to run adjacent to the "culticore" long-term systems trial. The specific objectives of these experiments are to quantify nutrient requirements of crops in rotations on Llanos Oxisols; to gain a better understanding of the dynamics, fluxes, and fate of phosphorus and nutrient cations (calcium, magnesium, and potassium); and to monitor developments in soil acidity following lime applications. Two designs are used. In one (replicated at three sites), several rates of lime, potassium, and magnesium are used in various combinations to monitor

fluxes of lime, potassium, and magnesium out of the surface soil and into the soil profile while observing the consequent changes in response to residual lime. The second (conducted at two sites) is a phosphorus rate experiment that permits comparisons of fresh and residual phosphate applications.

In terms of crop response, severe magnesium deficiency was observed in rice and cowpea at two of the three sites. However, relatively modest rates of lime were found to be sufficient to produce maximum yields of rice, cowpeas, and maize using the advanced germplasm from CIAT and the International Maize and Wheat Improvement Center (CIMMYT). Very preliminary data also suggest relatively small reductions of the effects of lime after a 1-year period. Responses of rice and cowpea at Matazul and maize at Carimagua to phosphate fertilizer reflect the very low levels of available phosphorus in these Oxisols. In general, virtually no yield was obtained without applied phosphorus. Nevertheless, application of phosphate fertilizer produced sharp responses; maximum yields were obtained with 40-60 kg-phosphate/ha on rice and 60-80 kg-phosphate/ha on maize. Cowpea, grown on residual phosphate applied to the previous rice crop in 1993, also produced maximum yields at 40-60 kg phosphate/ha. Residual effectiveness of phosphate fertilizer on these 'high phosphorus-fixing' soils also appears to be appreciable. However, for both lime and phosphate, it will be necessary to monitor these effects over a period of several years to quantify the input use efficiency and to determine their fate. For phosphorus, information of this type will enable the parameters to be established for the models describing the residual value and cycling of phosphate fertilizer, including the CENTURY model, which simulates phosphorus cycling in agroecosystems. It will also assist in the development of the phosphorus submodel of the CERES crop simulation models and enable the extrapolation of results to other environments.

Sustainability research in Uruguay

A key limitation for evaluating the sustainability of agricultural production systems is the period of time required for such evaluations. Thus, the concept of sustainability implies the consideration of relatively long research periods of time, which are prohibitive for the restrictive conditions of most research institutes. To overcome these limitations existing long-term experiments can be used to study the evolution of productivity levels, soil properties, economic results, and effects on the environment. For this purpose, IFDC is using one of the most valuable long-term experiments, which is conducted by the Instituto Nacional de Investigación Agropecuaria (INIA)-La Estanzuela in southwestern Uruguay. This 30-year-old experiment consists of seven cropping sequences. Because the plot size in this experiment is 0.5 ha, all field operations are performed with conventional farm equipment. Records of tillage operations and the amounts and costs of applied pesticides and fertilizer are available for the entire experimental period. Therefore, the results of this trial can be used to analyze the agronomic, environmental, and economic performance of the different cropping systems in the long term for conditions that are very similar to the farmers' conditions.

During 1994 our research in this long-term experiment in Uruguay concentrated on three contrasting cropping systems (CSs): CS-1 (continuous crops with no fertilizer applications), CS-2 (continuous crops with nitrogen + phosphate fertilizers), and CS-5 (3-4 years of pastures with phosphate fertilizers followed by 3-4 years of crops with nitrogen + phosphate fertilizers).

Evolution of Soil Organic Matter and Total Soil Nitrogen – The main objective of this analysis was to study the variation of the soil organic matter, total soil nitrogen, and forms of soil phosphorus as affected by cropping systems and by soil and crop management practices in the period 1963-91. An assessment of the sustainability of a production system must consider soil organic matter since it is a key factor in determining the soil's ability to supply nutrients and water to the

crops and the soil's physical condition for plant growth.

The cropping systems evaluated in this experiment can be divided into three main groups: (1) systems with continuous crops (CS-1 without fertilizers, and CS-2 with nitrogen and phosphate fertilizers); (2) systems in which crops alternate with short-duration (1-2 years) pastures (CS-4 and CS-7 with legumes, and CS-6 with annual grasses); and (3) systems with 4-5 years of crops followed by 4-5 years of multiannual pastures that include legumes (CS-3 with alfalfa or birdsfoot trefoil, and CS-5 with a mixture of white clover, red clover, and tall fescue).

Results of the first 30 years of research revealed that for all systems in the first two groups mentioned above, the factors that explained the majority of the variation in soil organic matter were the number of years with crops and the number of primary tillage operations. These were also the most important factors for the cropping systems with multiannual pastures during the crop stages.

The most detrimental effect of the number of years with crops on the soil organic matter was found for CS-1 (continuous crops without fertilizer). Application of nitrogen and phosphate fertilizers (CS-2) alleviated the negative effect of continuous cropping, but the annual reduction of soil organic matter was still large.

The inclusion of short-duration leguminous pastures (CS-4 and CS-7) clearly reduced the negative effects of cropping on soil organic matter. By the end of the period, when CS-4 was modified to include a pasture similar to the one in CS-5 and when the red clover in CS-7 was allowed to grow for an additional year, the reduction in soil organic matter was even lower.

Considering CS-5, a complete cycle of the system is comprised of two alternating stages: one with pastures (4-5 years) and one with annual crops (4-5 years). As expected, the soil organic matter increased during the pasture stages and decreased during the crop stages. The annual reduction of soil organic matter during the crop stages in this cropping system was the largest of all systems. The easily decomposable organic matter left by the pastures is probably the main cause for this drastic reduction in soil organic matter during the crop stages.

The data indicated that the increase of soil organic matter during the pasture stages was curvilinear with large increases at the beginning of the pasture cycle and smaller annual soil organic matter increases with the pasture age. The reduction of soil organic matter during the crop stages was also curvilinear with the largest decreases immediately after plowing the pastures.

Similar analyses were performed for the data for the total soil nitrogen of this experiment. The regression models that best fitted the data included the same variables, and the results and general conclusions were equivalent to the ones mentioned for soil organic matter.

In general, this initial analysis indicates that the only systems that presented adequate soil organic matter and total soil nitrogen balances in 30 years were the ones that included leguminous pastures. Application of fertilizers in systems with continuous crops reduced the losses of soil organic matter but were not sufficient to maintain levels of soil organic matter. Soil management practices that reduce erosion problems would clearly cause lower losses of soil organic matter for all cropping systems and would probably result in leveled (or even positive) soil organic matter and total soil nitrogen balances for CS-5, CS-4, and CS-7.

Plant Litter Decomposition Study – Crop and pasture litter decomposition is a fundamental factor in the soil organic matter dynamics of crop-pasture rotation systems. Litter inputs play a key role in determining the equilibrium level of soil organic matter achieved in different production systems. The amount and type of added residues affect the soil organic matter content and are crucial for the short-term availability of plant nutrients in crop rotation systems. Since litter degradation products are incorporated into various soil organic matter pools with different turnover rates, the type of residue and residue management are key factors in determining carbon and nitrogen stabilization in the soil organic matter, which in turn affects the physical condition of soils and their ability to supply nutrients and water to the crops.

The objective of the plant litter research conducted by INIA and IFDC was to study decomposition rates and nutrient release rates from contrasting plant residues as affected by cropping sequences, plant residue chemical composition, and plant residue management. Additional objectives were to compare results obtained under field and laboratory conditions and to develop a model for predicting decomposition rates and nutrient release rate of plant litter under field conditions.

The results indicated that the previous cropping history of the soil did not affect residue decomposition rates in the field experiment. Large differences were found in the decomposition rates of the different plant materials. For example, almost 80% of the white clover dry matter had disappeared 62 days after burial while the corresponding figure for the bermuda grass litter was 35%. These results have very important practical implications. For example, the very high decomposition rates of the white clover residue and its high nitrogen content indicate that large amounts of nitrogen would be released to the soil soon after a white clover pasture is plowed. This would result in very low use efficiency of this nitrogen by subsequent crops and potential problems of nitrate leaching to the groundwater. On the other hand, bermuda grass, which is a typical weed invading Uruguayan pastures, can act as an excellent trap for nitrogen, which would be slowly released during the growing seasons of crops planted after the pasture.

Nitrogen and phosphorus studies on the pastures of Brazil

Approximately 10% of the Amazonian tropical forests have been cleared in the past 20 years. The traditional method used for clearing 90% of these areas includes cutting the forest, removing high-value tree species, burning the remaining species, and planting pasture grasses (typically Brachiaria). Environmental concerns have led to numerous research projects for evaluating the sustainability of this practice by conducting nutrient balances in the soil. Research conducted by the Center for Nuclear Energy in Agriculture (CENA), University of Sao Paulo, has shown that the total carbon and nitrogen content of the soil increased with the shift from tropical forest to pastures in the Amazon region. Phosphorus is a key nutrient that can limit both pasture production and biological nitrogen fixation in these pasture-based systems. However, information on the evolution of soil phosphorus when shifting from forest to pastures in the Amazon region is very scarce.

During 1994 IFDC began collaborating with CENA on its research of pasture-based systems. The focus of this research is a study of the variation of different soil phosphorus forms when shifting from natural forest to sown pastures (2 to 80 years old).

The initial results suggest that total soil phosphorus increased when shifting from tropical forest to 80-year-old pastures. The organic soil phosphorus, inorganic soil phosphorus, and biologically active forms of soil phosphorus contributed similarly to the increase in total phosphorus.

Since the pastures are unfertilized, the only source to account for this phosphorus increase in the system is the forest. Two sources for phosphorus inputs can be identified: the ashes and the trunks that remain on the soil after the burning; and the forest roots that are unaffected by the fire. In addition, pasture roots grow well below the sampling depth of 0.3 m used in our research, where roots from the previously existing forest continue to be decomposed and phosphorus is transported from deeper layers.

Nutrient deficiency studies on Uruguay's dairy farms

The most common limiting plant nutrients in Uruguay are nitrogen and phosphorus. During the past decade a typical production system included 3-4 years of annual crops alternating with 3-4 years of pastures containing legumes. Nitrogen is biologically fixed during the pasture stage; therefore, phosphorus becomes the most limiting nutrient for crop production especially in the first years after the pastures are plowed. In more intensive production systems such as dairy farming, the situation is probably different.

The dairy production region in Uruguay has increased significantly during the past decade. This increase has resulted in larger extractions of plant nutrients through animal outputs and exports of nutrients from the producing areas.

The fertilizer recommendations for pastures in several countries account for nutrient losses due to animal factors and to silage and hay production; thus, the nutrient balance in the ecosystem is considered when determining fertilizer requirements. Better prediction of fertilizer needs in Uruguay could be achieved if both the expected nutrient balance and the current nutrient availability in the soil were considered.

Because triple superphosphate (TSP) has been the most commonly used phosphate fertilizer in the dairy-producing area of Uruguay, sulfur deficiencies may have resulted. Recent soil testing results from western Uruguay suggest that potassium may also be limiting crop and pasture production in some dairy farms. In summary, there is no available information on the current soil fertility status with respect to sulfur and potassium in the dairy-producing region of Uruguay. There is much more information on the soil nitrogen and phosphorus status from these areas, but including these nutrients in the present study would allow a more comprehensive approach to diagnose and correct soil fertility problems in the region.

During 1994 INIA-Uruguay and IFDC started a collaborative project, partially funded by The Sulphur Institute, with the main objective of diagnosing the current soil fertility status with respect to sulfur, potassium, calcium, magnesium, nitrogen, phosphorus, and micronutrients in the dairy-producing region of Uruguay. Plant and soil samples were obtained from 60 dairy farms, and results of plant analyses were compared to sufficiency levels reported in the literature. IFDC and INIA scientists are also studying the relationship of the measured nutrient levels with soil properties and soil management practices to identify situations that are likely to result in deficiencies of one or more of the studied nutrients.

The data indicated that more than 90% of the fields were deficient in nitrogen, and more than 80% were deficient in sulfur, probably because the dairy production systems in the region are very exhaustive for the soil. On the other hand, the 1993/94 maize-growing season presented much higher rainfall than average, which probably resulted in low use efficiency of nitrogen and sulfur. Finally, the data collected on fertilizer use indicate that farmers use very low rates of nitrogen (typically 20-30 kg/ha applied at planting), whereas no sulfur fertilizer was applied.

The results also indicated that 40%-50% of the fields were deficient in potassium, which was unexpected since soils in Uruguay typically have high contents of exchangeable potassium. However, the intensive dairy production system and the general lack of potash applications are now resulting in deficiencies of that nutrient. The only micronutrient that has been analyzed is zinc, and the preliminary results are also showing deficiencies.

These results are very important for the region since this is the first time that deficiencies of sulfur, potassium, and micronutrients have been reported. The results also have regional relevance since the dairy production systems of Argentina and South Brazil are very similar to the ones in Uruguay.

Watershed Management in West Africa

The main challenges confronting the countries of West Africa are feeding their people and helping them to find gainful employment. They must produce more food to feed their burgeoning populations. At the same time, they must rescue the land from degradation, increase crop production, and protect the environment. Through its work in the Watershed Management Program, IFDC-Africa is helping to provide answers to some of these challenges.

Improving crop yields using plant residues and inorganic fertilizers

This Malian farmer was a partner in an IFDC fertilizer research project in his country.

For the past few years IFDC has been conducting long-term field experiments at Sadore, Niger, in the Sahelian zone and Tara, Niger, in the Sudano-Sahelian zone to study the effect of mineral fertilizers and crop residue application on soil productivity and chemical properties. Preliminary results indicate that, in the Sahelian zone, pearl millet and cowpea yields were increased significantly by both fertilizer and crop residue application; highest yields were obtained when fertilizers were combined with crop residue mainly because of the additive effects of both amendments (Table 2).

By contrast, in the Sudano-Sahelian zone, application of crop residue alone or with chemical fertilizers did not result in a significant increase in pearl millet yields over the first three years. The rate of decomposition of crop residue was much higher in the Sudano-Sahelian zone than in the Sahelian zone.

Application of crop residue increased significantly the organic matter content of soil and the effective cation exchange capacity at Sadore but not at Tara. For both sites the application of mineral fertilizers alone leads to decreasing base saturation, decreasing pH, and increasing aluminum saturation. The apparently contradictory results obtained in response to crop residue application suggest that much needs to be done to investigate the mechanisms of the effects of crop residue on crop growth in different climates and to monitor more closely the dynamics of organic matter turnover in the different soils.

Table 2. Effect of Mineral Fertilizers and Crop Residue on Pearl Millet Total Dry Matter (TDM) Yields (Sadoré, Niger)

Treatment	Pearl Millet TDM Yield					Cowpea Fodder Yield			
	1990	1991	1992	1993	1994	1991	1992	1993	1994
	(kg/ha)					(kg/ha)			
Control	900	722	1,300	1,238	813	969	2,195	840	1,063
Crop residue (CR)	1,611	2,276	2,882	3,209	1,663	1,896	2,920	893	2,363
Fertilizer (F)	1,803	2,923	3,898	3,481	2,375	2,837	3,840	2,010	2,250
CR + F	4,312	6,173	8,098	6,393	5,204	4,841	6,140	2,400	6,421
LSD 0.05	710	490	1,393	1,650	738	1,591	682	390	952
CV (%)	21	10	22	29	18	28	16	16	20

A Nigerian farmer who participated in IFDC's on-farm research.

Supplying micronutrient requirements of Sahelian soils

Previous researchers have shown the importance of nitrogen, phosphorus and organic amendments such as manure for the improvement of crop production in the Sahelian zone. There is increasing research evidence of the importance of molybdenum for crop production. The availability of molybdenum is known to decrease with a decrease in soil pH, and for the acid sandy soils of the Sahel, molybdenum deficiency could constitute a serious problem for crop production. Molybdenum available in the soil has been found to be insufficient to meet the requirement for symbiotic nitrogen fixation of legumes such as groundnut and cowpea.

Between 1991 and 1994 experiments conducted at Sadore included treatments of nitrogen, phosphorus, manure, carbofuran and molybdenum applied or not applied as the first criteria. The crops tested included pearl millet, groundnuts, and cowpea. With few exceptions application of nitrogen, phosphorus and manure resulted in a highly significant yield increase. The significant yield response to nitrogen for legumes indicates that the predominantly sandy soils of the Sahelian zone may be deficient in molybdenum, which is required for efficient symbiotic nitrogen fixation. There is a positive interaction between phosphorus and manure; the

effect of manure was less pronounced in the presence of phosphorus application. This suggests that high yields could be obtained with the combination of smaller quantities of phosphate fertilizer and manure.

In the cases where the interaction between nitrogen and molybdenum is significant, a greater response to molybdenum was observed in the presence of nitrogen than when nitrogen was not applied. This suggests that legumes will need application of small amounts of nitrogen as a starter fertilizer. Where the interaction between manure and molybdenum was significant, yield was less affected by the application of molybdenum when manure was applied. This suggests that manure already contains sufficient amounts of molybdenum required by the crop.

Agricultural productivity could be dramatically increased with the improvement of soil fertility. For example, pearl millet grain yield in 1991 and groundnut fodder yield in 1993 increased, respectively, by 550% and 552% over the control with the application of nitrogen, phosphorus, manure, carbofuran, and molybdenum. Although nitrogen, phosphorus, and manure are the most critical for yield enhancement, the application of molybdenum and carbofuran increased yield over control by 8%-72% for pearl millet and by 20%-73% for the legumes. The highest yields are obtained when both organic and inorganic fertilizers are applied with chemicals to control nematodes.

IFDC's Impact in Africa
The Nigerien Example

Thirty farmers in Niger, who participated in an IFDC research project, have seen their millet yields increase by 250%. The farmers tested the effect on millet production of applying 30 kg of P_2O_5 per hectare as phosphate rock from their country, or its partially acidulated form, or as a commercially available single superphosphate. As a result of IFDC's work, fertilizer use in Gobery, Niger, has increased from 2 mt of single superphosphate in 1982 to a total of more than 115 mt of SSP, urea, and compound NPK fertilizers in 1988. In 1994, 98% of the farms in Gobery were fertilized. IFDC has tested its Nigerien success in Mali and Nigeria. Farmer participation in the validation of fertilizer-use technologies has become the centerpiece of the IFDC-coordinated West African Fertilizer Management and Evaluation Network (WAFMEN), composed of 19 member countries.

Improving soil fertility using local phosphate rocks

One of the major constraints to the direct application of phosphate rock is its dustiness. Farmers are also aware that phosphate rock must be supplemented with other nutrients such as nitrogen, potassium and sulfur, and sometimes micronutrients. For unreactive rocks such as Parc-W phosphate rock from Niger, the mixture of phosphate rock with TSP by compaction (1:1 phosphorus ratio from each component plus urea and potassium chloride) can increase the availability of phosphorus in the product.

Recent laboratory and greenhouse studies showed that iron and aluminum oxide contents of phosphate rock can significantly hamper the water solubility and agronomic effectiveness of partially acidulated phosphate rock (PAPR) made from the rock. In field experiments it was previously concluded that Tahoua PAPR was not a desirable product because acidulation of this rock with high iron and aluminum oxide contents resulted in a material that contained relatively low amounts of water-soluble phosphate. Some of the water-soluble phosphate in Tahoua PAPR was converted to citrate-insoluble phosphorus and thus became less available to the plant. Compaction of Tahoua with TSP resulted in a more desirable product. The data in Table 3 indicate that the compacted products are similar in properties to PAPR and suggest that compaction is an alternative technology to produce cost-effective phosphate fertilizers from local phosphate rocks.

Table 3. Response of Pearl Millet Total Dry Matter to Different Sources of Phosphate Fertilizer (Bengou, Niger, 1993 and 1994)

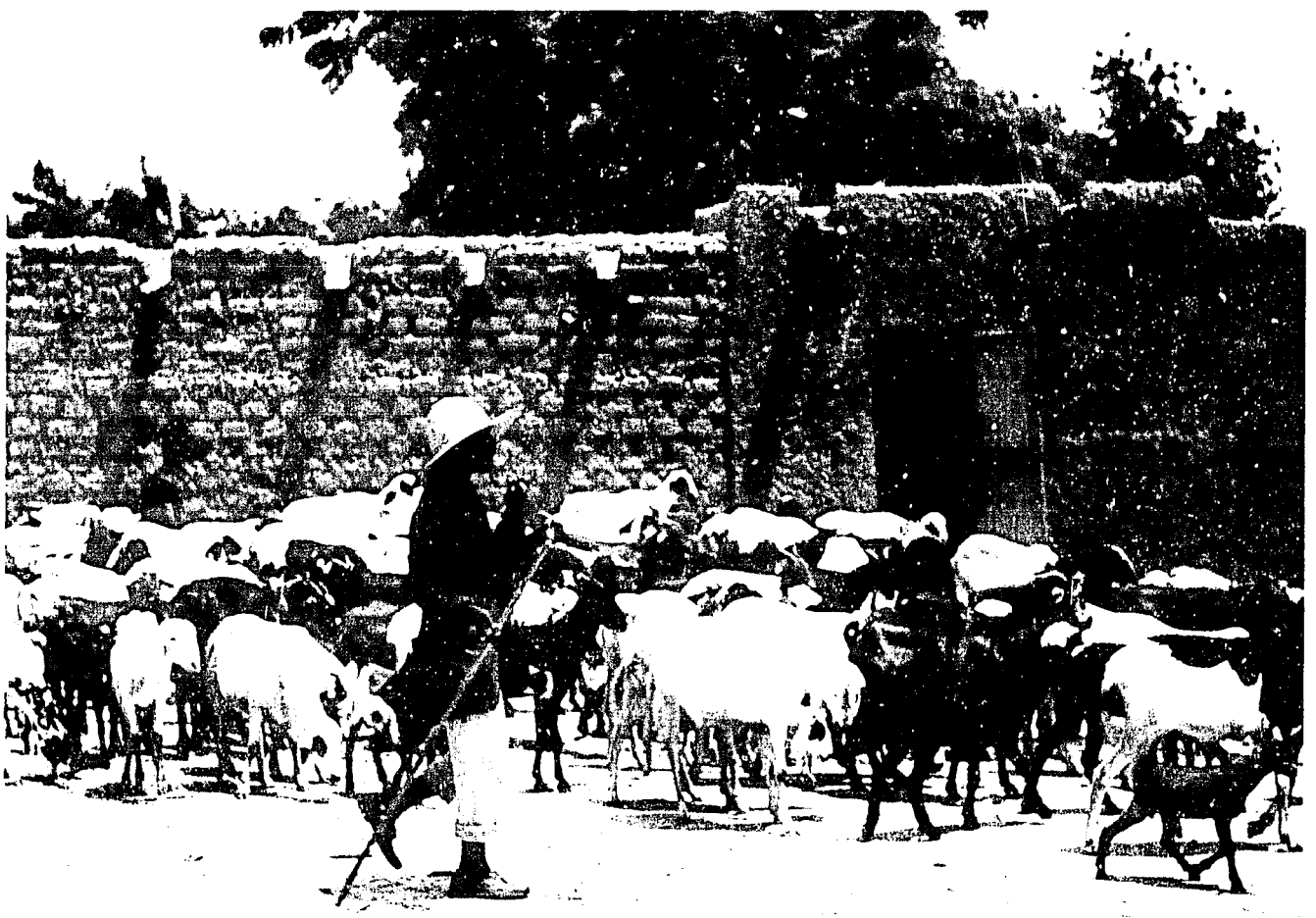
Treatment	TDM, 1993 (kg/ha)	RAE (%)	TDM, 1994 (kg/ha)	RAE (%)
1. Control	3,593	-	2,196	-
2. Single superphosphate (SSP)	5,424	100	3,913	100
3. Triple superphosphate (TSP)	5,288	93	3,600	82
4. Parc-W PR	4,551	52	3,288	64
5. Tahoua PR	3,656	3	3,123	54
6. Parc-W PAPR	4,428	46	3,067	51
7. Compacted Tahoua PR with urea and KCl	4,401	44	2,921	42
8. Compacted Parc-W PAPR with urea and KCl	5,427	100	3,596	82
9. Compacted Tahoua PR + TSP with urea and KCl	5,855	124	4,254	120
10. Compacted Parc-W PR + TSP with urea and KCl	5,852	123	3,908	100
LSD 0.05	987	-	1,024	-
CV (%)	14	-	21	-

RAE= Relative agronomic effectiveness

TDM = Total dry matter

1. $RAE = \frac{\text{Yield of test treatment - yield of control}}{\text{Yield of SSP - yield of control}} \times 100$

Using phosphate fertilizers with grain seeds



Farm animals are an important segment of African agriculture.

To provide the phosphorus nutrient to the plant at the germination stage, seeds can be coated with phosphate fertilizer to promote plant growth during the early stages. In order to simulate the seed coating technology, an equivalent of 2 kg/ha of phosphate fertilizer was hill-placed with seed at planting in a pot experiment using different types of phosphate fertilizers. The results indicate that for most of the phosphate fertilizer sources, total dry matter yield of pearl millet at 40 days after planting was dramatically increased with this technique of phosphate application. This finding has significant implications for resource-poor farmers in the West African semiarid tropics.

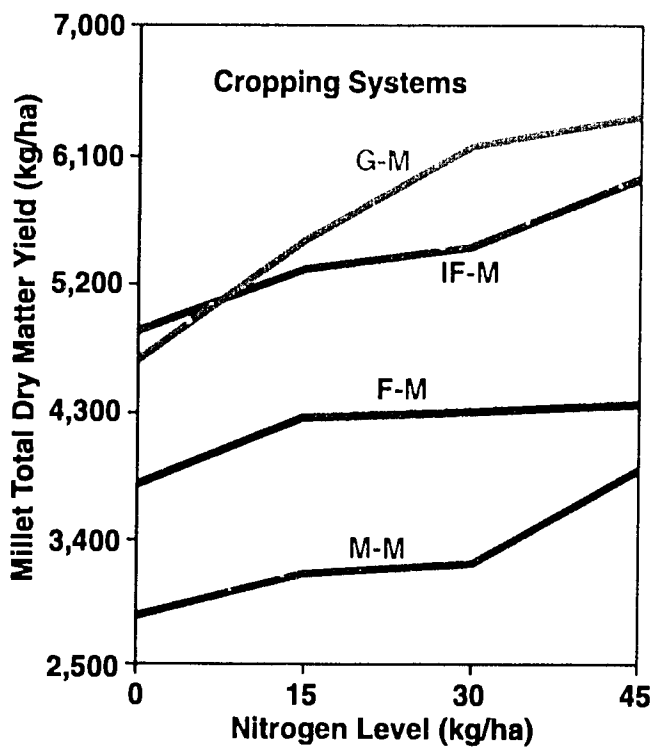
Rotating crops for sustainable production in the Sahel

IFDC's Impact in Africa

IFDC has supported Africa in capacity and institutional building; promoting improved efficiency in fertilizer marketing; and developing research, soil management, and conservation activities that are conducive to increased food production and reduced desertification, preservation of the environment, and prevention of the population exodus to urban areas.

In the past, agriculture in West Africa was sustainable because farmers would shift from a cultivated site to an uncultivated one before crop yields severely declined; thus, fields were able to recover their nutrient losses under natural regrowth. With current population growth rates, croplands have been subjected to worsening pressures and cannot produce food on a sustainable basis.

In the Sudano-Sahelian zone of West Africa, continuous cropping of pearl millet resulted in lower yields across all nitrogen rates than when pearl millet was rotated with cowpea or groundnut. Further investigations on rotation between pearl millet and improved fallow of legumes (stylosanthes pachycarpa) gave similar results as the rotation with groundnut (Figure 1).



Note: G-M = Groundnut - Millet
IF-M = Improved Fallow - Millet
F-M = Fallow - Millet
M-M = Millet - Millet

Figure 1. Effect of Nitrogen and Cropping Systems on Pearl Millet Grain Yield (Tara, Niger, 1989 to 1992 Rainy Season).

Reducing acidity with small doses of lime and manures

The main causes of the infertility of acidic soils in West Africa are the aluminum and manganese toxicities and the deficiency or unavailability of phosphorus, calcium, magnesium, and molybdenum. These factors can act independently or together and can inhibit the survival and functioning of rhizobia, mycorrhizae, and other soil microorganisms. Some investigators in the region have noted that the problems of low soil pH, high aluminum saturation, and reduced yield increased with annual application of mineral fertilizers and that the problems were alleviated or even prevented in treatments containing manure application (Figure 2).

In field studies where lime and phosphorus (as single superphosphate) were applied to sandy soils, the use of phosphate and lime increased yields significantly, but there was no significant interaction between phosphate and lime.

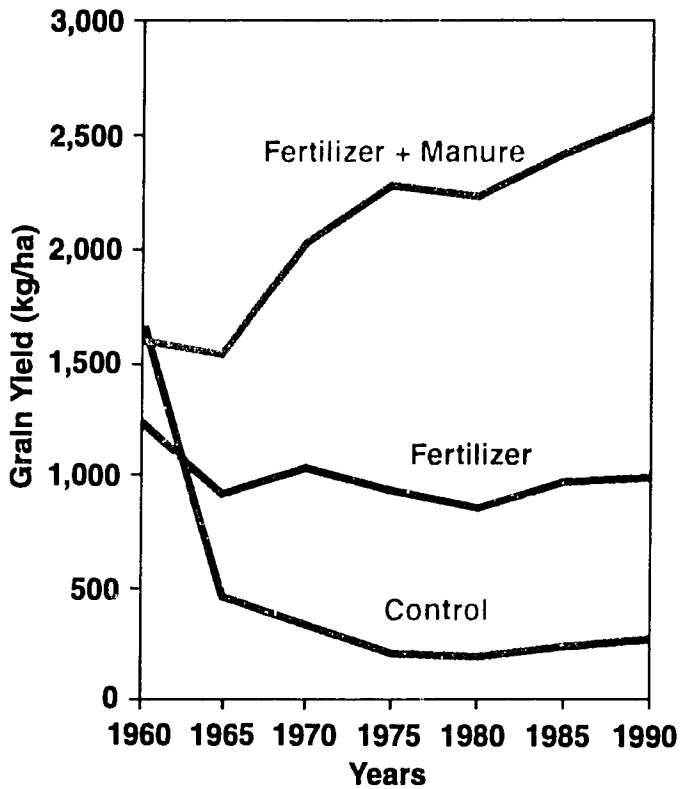


Figure 2. Sorghum Grain Yield as Affected by Mineral and Organic Fertilizers Over Years, 1960-90.

Global Environmental Research

Efficient and environmentally sound fertilizer use can prevent the degradation of the resource base and sustain high crop yields. On the other hand, if fertilizer is not managed properly and is used excessively, it may cause harm to the environment through nitrate leaching, eutrophication, and greenhouse emissions. However, through proper timing, placement, management, and soil analyses, such adverse effects can be reduced considerably. Because fertilizer use levels are still very low in many developing countries, there is little danger that fertilizers will have adverse environmental impacts in these areas. On the other hand, inadequate use of fertilizer may lead to further degradation of the resource base. IFDC's scientists are seeking to identify and develop technologies that will maximize potentially beneficial effects and minimize potentially harmful effects.

Global Environmental Research

Greenhouse gas emissions from flooded rice

Joint research between the Rockefeller Foundation and the IFDC-IRRI Collaborative Project was conducted to quantify greenhouse gas emissions from flooded rice systems. During rice cropping the effects of integrated nutrient management and drainage event were investigated. In integrated treatments of urea with green manure and rice straw, grain yields in both the 1993 and 1994 dry seasons and the 1993 wet season at the IRRI farm were similar to the yields when all nitrogen was supplied by urea alone or with ammonium sulfate. The mean grain yield during the dry season was 6.0 tonnes/ha and 5.3 tonnes/ha during the wet season. Green manure and rice straw supplied 20% and 16% of total nitrogen during the dry season and 33% and 27% during the wet season, respectively. However, organic amendment led to a 10-fold increase in methane fluxes in continuously flooded and in drained plots (Table 4). During the fallow period the methane fluxes were considerably lower; nonetheless, the organic amendment effect dominated the fluxes. Straw and green manure incorporation had a beneficial effect in reducing the nitrous oxide emission. The emission of nitrous oxide from lowland rice soils is of great concern because nitrous oxide contributes to the global warming effect and atmospheric chemistry – destruction of ozone in the stratosphere. Considering the residence time, nitrous oxide is about 300 times and methane about 15 times more radiatively active than carbon dioxide on a mass basis. Overall, organic amendments resulted in increasing the "greenhouse gas effect."

Table 4. Cumulative Methane and Nitrous Oxide Fluxes as Affected by Organic Amendment and Water Management, IRRI Farm

Treatment	Methane		Nitrous Oxide	
	Continuous Flood	Drained	Continuous Flood	Drained
	---- (mg C/m^2)----		---- (mg N/m^2) ----	
Urea				
93 dry season	-	800	-	8.9
93 wet season	2,700	-	13.1	-
94 dry season	1,300	500	25.9	63.8
Ammonium Sulfate				
93 dry season	-	200	-	22.9
93 wet season	1,000	-	9.7	-
Green Manure				
93 dry season	-	7,400	-	12.1
93 wet season	18,200	-	5.5	-
Straw				
93 dry season	-	16,400	-	5.7
93 wet season	29,300	-	5.9	-
94 dry season	27,800	15,900	2.8	16.5

During the fallow periods the residual effect of nitrogen sources on nitrous oxide and methane emissions was monitored (Table 5). Moderately high, continuous nitrous oxide fluxes were evident during these fallow periods compared with the rice cropping seasons. The third fallow period of the experiment was unusually wet with very little accumulation of nitrate-nitrogen; hence, nitrous oxide emissions were low. Methane emissions during the fallow periods were significantly lower than those during the rice cropping phase while the inverse applied to nitrous oxide emissions.

Table 5. Cumulative Methane and Nitrous Oxide Fluxes as Affected by Organic Amendment From Previous Rice Cropping Season, IRRI Farm

Treatment	Methane (mg C/m²)	Nitrous Oxide (mg N/m²)
Urea		
92-93 wet-dry fallow (46 days)	4.2	61.0
93 dry-wet fallow (36 days)	13.6	171.3
93-94 wet-dry fallow (89 days)	291.0	19.3
Ammonium Sulfate		
92-93 wet-dry fallow (46 days)	6.2	94.3
93 dry-wet fallow (36 days)	8.9	119.8
93-94 wet-dry fallow (89 days)	157.4	16.0
Green Manure		
92-93 wet-dry fallow (46 days)	201.4	78.0
93 dry-wet fallow (36 days)	19.5	182.7
93-94 wet-dry fallow (89 days)	644.4	18.1
Straw		
92-93 wet-dry fallow (46 days)	23.0	103.8
93 dry-wet fallow (36 days)	16.5	171.6
93-94 wet-dry fallow (89 days)	178.3	36.1

The previous season's nitrogen management continued to have some effect; methane emissions were higher in the organic amended plots. During the wet fallow periods, rice soils could be important sources of methane. Overall, rice soil during the fallow periods is a more important source of nitrous oxide than the actual flooded rice cropping period. Hence, judicious management of soil nitrogen and residue nitrogen during the fallow period is crucial in terms of resource savings and capture, as well as environmental protection.

Impact of phosphorus fertilizer use on cadmium in soils and plants

The environmental impact of phosphorus fertilizer use continued to be of research interest to IFDC scientists in 1994. Phosphorus fertilizers contain various amounts of heavy metals including cadmium. Cadmium is toxic to animals and human beings, and concern has been expressed by environmentalists that long-term application of fertilizers containing cadmium could increase cadmium in soils and would eventually enter the food chain through crop uptake.

In 1992 a multiseasonal pot trial was established at IFDC to monitor the impact of repeated annual applications of normal rates of phosphate fertilizers including North Carolina phosphate rock containing 47 mg cadmium/kg, partially acidulated Togo phosphate rock (Togo PAPR) with 40 mg cadmium/kg, partially acidulated Morocco phosphate rock (Morocco PAPR) having 8 mg cadmium/kg and TSP, which contained 7 mg cadmium/kg. Hartsells silt loam (pH 4.8) was fertilized with incremental doses of 50 and 100 mg phosphorus/kg soil

annually, and different crops were grown. During the second year, maize followed by cowpeas was grown as the test crop. Soil samples collected after harvesting the crops showed that total cadmium as expected was highest in soils fertilized with North Carolina phosphate rock (NCPR) followed by that with Togo PAPR, TSP, and Morocco PAPR. Bioavailable cadmium however was low – less than 20 micrograms/kg in all cases. With an increase in bioavailable phosphorus, biomass of maize increased, and the concentration of cadmium in plant tissues decreased while total cadmium uptake increased.

The concentration of cadmium in plant tissues varied with the type and amount of fertilizer used and the part of the plant that was analyzed. In cowpeas, cadmium was lowest in seeds – 70 micrograms/kg in all cases except in the control. Roots had the highest cadmium in tissues (Figure 3). Total uptake of cadmium from soils receiving North Carolina phosphate rock and Togo PAPR was the same.

Plants grown in soils fertilized with phosphates show less cadmium in plant tissues than plants grown in soils with phosphorus stress. This is because phosphorus stimulates biomass production, and this in turn dilutes the concentration of cadmium in plant tissues. To verify this contention, pot trials were carried out using 18 soils widely different in physical and chemical characteristics. Cadmium was added to each soil at 200 micrograms/kg rate. Phosphorus was added to each soil in one set of soils at 200 micrograms/kg rate while another set did not receive any phosphorus. Maize was grown as the test crop. Cadmium concentration in plant tissues was consistently higher in plants grown in unfertilized soil. With an increase in plant biomass, cadmium concentration in tissues decreased. This would suggest that in phosphorus-deficient soils with a high cadmium content, application of phosphate fertilizers not only increases yield but also reduces concentration of cadmium in plant tissues.

Availability of cadmium in soils is influenced by several factors such as pH, organic matter content, and

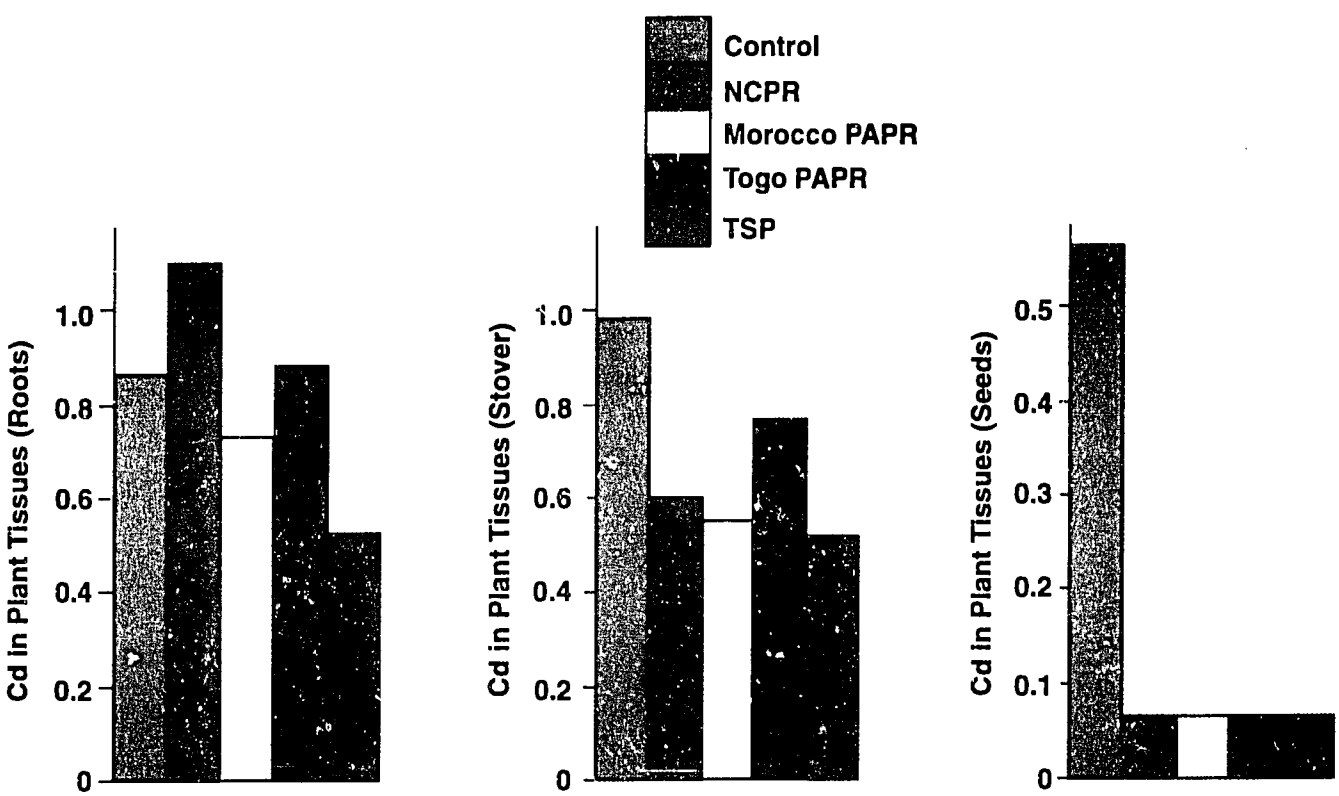


Figure 3. Cadmium Concentration (mg/kg) in Roots, Stover, and Seeds of Cowpeas Fertilized With Phosphate Fertilizers Containing Different Amounts of Cadmium.

cation exchange capacity. Greenhouse studies with maize grown on 18 soils including acidic, alkaline and calcareous soils treated with 200 micrograms cadmium/kg of soil demonstrated that cadmium in plant tissue correlated well with exchangeable calcium and magnesium, the sum of bases, and clay content. Correlation between cadmium in the plant tissue and pH was not as good as reported in the literature. Likewise, the correlation between the cadmium in plant and soil organic matter was not very good.

To investigate the effect of application of fertilizers containing high cadmium in soils under different agroecological systems, collaboration was established by IFDC with the Asian Vegetable Research and Development Center (AVRDC), Taiwan, as well as Ruakura Agricultural Research Centre, New Zealand. Experiments were carried out at AVRDC to study the influence of superphosphates produced from North Carolina phosphate rock and Togo phosphate rock on cadmium uptake by vegetable crops. Field trials are being initiated in New Zealand to investigate the influence of these fertilizers on cadmium uptake by pasture species.

IFDC's Impact in Latin America

IFDC's research and development work has important implications for the preservation of the environment. A good example is found in the acid soil savannas of Latin America in Brazil, Colombia, and Venezuela. Besides increasing crop production, a positive externality of our phosphate research work is that the acid savannas can be reclaimed through the use of phosphate rock. The alleviation of deforestation, the increase in soil fertility and organic matter, and the reduction of carbon dioxide emissions to the atmosphere will result.

Phosphate rock as an investment in natural resource capital

Previous investment in intensified agriculture using high-yielding varieties and fertilizer technology produced tremendous increases in food production and prevented the massive food deficits predicted by many people for Asia in the late 1960s and early 1970s. However, sub-Saharan Africa continues to represent a major concern as increases in food production are outstripped by population growth while degradation of natural resources proceeds at an alarming rate. In this region, low levels of soil fertility and land degradation exist and must be dealt with so that increased agricultural production can be achieved. In much of sub-Saharan Africa, phosphorus is the primary nutrient that limits biomass production and is a key component to solving the problems of low soil fertility/land degradation.

In a study commissioned by the World Bank in 1994, IFDC in collaboration with the International Centre for Research in Agroforestry (ICRAF) identified issues regarding the use of phosphate rock as an amendment to replenish the

soil phosphorus in sub-Saharan Africa. Once the soil phosphorus reserves are replenished, a primary soil fertility constraint to improved crop production would be removed, and the yearly cost to restore the estimated crop-induced phosphorus export/losses with small annual application of commercial phosphate fertilizers could be recovered through yield increases, thereby protecting the soil phosphorus reserves from depletion.

Replenishment of phosphorus would not only improve agricultural production but would contribute to the restoration and maintenance of natural resources. Phosphorus is essential for root growth, biological nitrogen fixation (BNF) by legumes, and organic matter accumulation and is not subject to the loss mechanisms other than erosion. Soil phosphorus is not easily recycled but must be increased primarily through the addition of external inputs, but once applied it provides residual value for subsequent crops. A large portion of the land currently farmed by the small land holders in sub-Saharan Africa is so deficient in phosphorus that only small increases in productivity can be obtained through otherwise environmentally sustainable practices, e.g., crop rotations, use of legumes, and residue management. Thus, these factors support the replenishment of soil phosphorus as an investment.

Soil phosphorus can be viewed as two distinct fractions, "agricultural phosphate" and "capital phosphate" or flow resources and capital stock, respectively. While "agricultural phosphate" is that quantity of phosphorus available to plants during a single cropping season, capital phosphate represents the major stock resource held in reserve providing long-term benefit through its slow recycling chemistry with some release to "agricultural phosphate" over time. "Agricultural phosphate," which constitutes a much smaller fraction of total soil phosphorus as compared with "capital phosphate," affects the annual level of crop yields, but ecosystem soundness is dependent on the maintenance and residual characteristics of the "capital phosphate" fraction.

Replenishment of "capital phosphate" in sub-Saharan Africa would help break the vicious cycle of nutrient capital depletion and soil degradation presently occurring. Estimates indicate that four-fifths of the cropland and pasture land in sub-Saharan Africa have some degree of degradation. While much of the degradation is attributed to erosion, an important underlying factor is nutrient depletion occurring within the soil resource base due to present agricultural practices. In the past nutrient capital was maintained through the traditional practice of shifting cultivation involving low-input, low-yielding agriculture. This strategy was satisfactory when population densities were considerably lower and when most people were engaged in the production of their own food. Today, populations are concentrated in cities requiring food imports from the surrounding countryside while farmers are involved in more intensive cropping practices such as cultivating more fragile marginal lands, allowing shorter and poorly managed fallow periods, and using little, if any, mineral or organic fertilizer. These practices of increased cropping intensity without nutrient/input replenishment are progressively degrading the soils of sub-Saharan Africa.

This process can be reversed with proper crop management practices including the judicious use of mineral fertilizers, the recycling of organic sources of plant nutrients, BNF technologies, and conservation tillage. Studies in the region have shown that phosphorus replenishment can significantly increase yields. In the semiarid regions of West Africa, "capital phosphate" can be increased through annual additions of relatively small amounts of phosphate fertilizers. In the humid zones larger quantities of phosphorus will be required to overcome the phosphorus sorption capacity of these soils, but once this "capital phosphate" fraction is satisfied, the potential for agricultural productivity would be greatly enhanced.

The smallholder farmer lacks the financial resources required to replenish soil "capital phosphate." However, if the "capital phosphate" were available, the cost to the farmer for annual applications of "agricultural phosphate" to compensate for harvested offtake and provide simultaneous protection of the "capital phosphate" investment should be recovered through consequent yield increases.

The next phase of the project will be to conduct an economic feasibility study to assess the effect of using local phosphate rock and related products as a capital investment in soil fertility restoration and maintenance in selected countries of sub-Saharan Africa. Available data and information,

e.g., yield effects, costs of producing, marketing, distributing, and applying phosphate rock and related products, will be examined to estimate private, social and environmental costs/benefits generated from such an activity. Policy, institutional, infrastructural, and sociocultural conditions necessary for the success of the phosphate rock investment will also need to be identified.

Unless the farmers of sub-Saharan Africa are offered an alternative, they have little recourse but to continue the practice of "phosphorus nutrient mining," which eventually leads to abandonment of degraded lands, encroachment on marginal lands, deforestation, desertification, erosion, and migration to urban areas. Such practices will only increase the already prevalent negative soil phosphorus balance and will exacerbate the spiral of resource degradation and poverty. Establishment of any sustainable agricultural production systems will be precluded due to the process of liquidation of the soil natural capital stock because farmers of the present generation have no alternative other than to "consume" soil natural capital stock at the expense of the environment and welfare of future generations.

Management Information Systems

Management information systems are valuable tools that can help decisionmakers in planning and evaluating agronomic practices to create sustainable agricultural development. In Eastern Europe, Asia, Africa, and Latin America, during 1994 IFDC's researchers continued to work on projects to implement information systems and decision support systems to support agricultural development activities. Working in collaboration with national and international agricultural institutions, IFDC's systems modeling scientists develop crop and nutrient models, which are then linked with socioeconomic models, expert systems, and geographic information systems.

Area and socioeconomic surveys of agricultural production in Albania

Survey Purpose

During 1994 IFDC conducted socioeconomic and crop area surveys in Albania. The main objective was to support and assist Albania's development of viable agricultural production strategies and to help promote and enhance a free-market agricultural sector. The surveys provided the Ministry of Agriculture and Food (MOAF) and the private sector with factual information on the socioeconomic characteristics of rural families, farming practices, production, and use of agricultural inputs during the 1993/94 cropping season. The surveys were conducted in collaboration with officers of the Directorate of Statistics of the MOAF located in 25 of the 36 districts in the country. In the socioeconomic survey 649 farm households were interviewed, and 4,000 farmers were randomly selected across the country for the crop area survey.

The information collected during the surveys contributed to activities initiated by IFDC in 1992, which were conducive to the establishment of a national agricultural information system, a high priority in the country. Important outcomes from these activities include: (1) provision of socioeconomic and agricultural indicators for determining production bottlenecks, evaluating farming conditions, and appraising agricultural production through the use of fertilizers and other inputs; (2) development of an area sampling frame to monitor agricultural land use and forecast production of crops. The system constitutes a framework to support studies for about 500,000 private farmers and speed the process for the generation of national agricultural statistics; (3) provision of a basis for the management of agricultural information systems by designing and establishing attribute and geographical databases linking information on crop area, production and socioeconomic data to facilitate the monitoring and development of agricultural programs; and (4) development of national capacity by training government officers on the fundamentals of structuring information and use of sampling techniques to carry out surveys, data collection, analysis, and reporting.

Survey Information

Albania's transition to a market economy; the privatization reforms and land distribution; the formation of small-scale, family-oriented farm units; and the promotion of agricultural enterprises are requiring updated information on farm production, constraints, and the use of resources. Reliable information will be required for a sustainable exploitation of land and environmental conservation. Surveys were designed to explore the means by which such data can be provided and used for training purposes.

The surveys contain data that characterize land use area, the farm, the farmer, the family, resource endowments, crop and farming systems, prices and costs, income, constraints in production, and resource use. A survey system has been structured to be easily updated and managed. The sampling frame supporting this system is composed of permanent identifiable agricultural regions and sampling units composed of farms. A particular characteristic of the agricultural regions is that they are pieces of land with similar topography that include multiple farming activities.

Stratification by agricultural regions and primary sampling units permitted better characterization of farm management activities, production systems, resource use, and evaluation of farm inputs and

outputs. The institutional support and social characteristics of farms have also been included and have been associated with the physical and economic features of regions and farms, thus characterizing areas for future development interventions.

With the land reforms, the principal feature of the agricultural sector is the scarcity of agricultural land (662,244 ha or 23% of total land). This structural problem has been aggravated by a number of constraints, principally those concerned with agricultural production. Many of these constraints have been identified and monitored in the surveys. They are principally associated with the use and availability of resources such as irrigation, mechanization, labor, credit, fertilizers, and seeds. Particularly, in the case of fertilizers, this input constitutes about 20% of the total variable costs of farm production. Demand for fertilizer is increasing, and the ability of the country to supply this increasing demand is limited. The ratio between production and apparent demand is about 0.21, which is lower than that in many developing countries. The actual consumption of mineral fertilizers amounts to 46,239 tonnes, covering only 30% of the total arable land. The apparent demand to fertilize at least 80% of the arable land amounts to 185,000 tonnes of mineral fertilizers. A scenario, including estimates of actual crop productivity and its association with the actual fertilizer use by agricultural regions, is presented in Figure 4.

In summary, reforms in Albania have created broad areas of information requirements. The MOAF Directorate of Statistics is responding to these needs, and the survey systems implemented represent an important initiative in this response. There is growing recognition of the need to support farmers, private farmer organizations, and research and extension workers in the field both by contributing to the general information environment in which they work (farming, traders, business) and, more directly, by providing them with support material, and updating their own technical expertise and knowledge. With the current social and economic transformations occurring in Albania and the decline of the centralized system, there will be much greater scope to use information technology and coordinate services with the government and the academic, business and financial, and development communities.

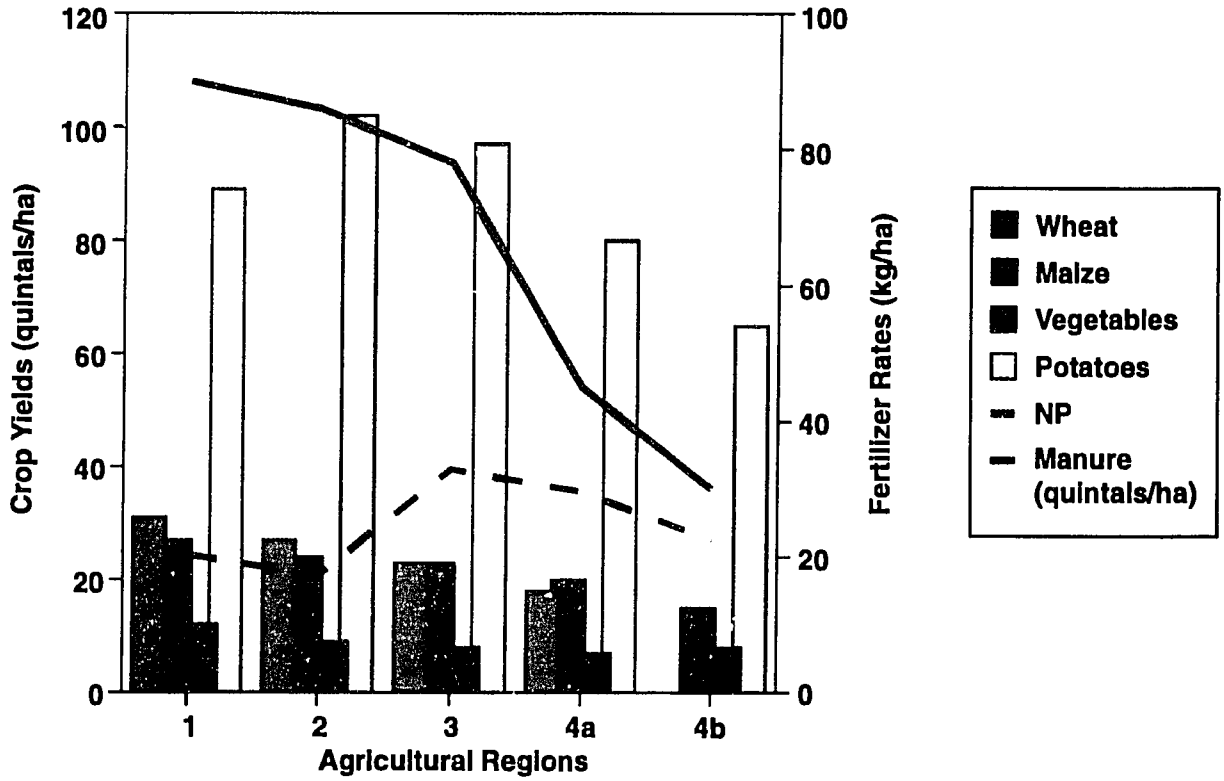


Figure 4. Crop Yields and Fertilizer Use in Albania.

A systems approach to restructuring agriculture in Albania

The liberalization of state controls, the distribution of land for private cultivation, and the establishment of private sector dealers for agricultural inputs are leading to the creation of a dynamic agricultural system in Albania. Old ways of generating and providing information, which were once controlled completely by the state, are being supplanted by a quantitative systems approach to deriving recommendations and options for growers, input dealers, and policymakers. This approach is being implemented in Albania by training researchers, teachers, businessmen, and policymakers in the use of simulation and Geographic Information System (GIS) tools. As part of this approach, the value of old experimental data is being extended by using them to calibrate and test crop growth models, new experiments are being conducted to train researchers in the field generation of data needed for simulation models, and weather and soil databases are being assembled into a GIS. The ultimate goal of this effort is the creation of a comprehensive management information system that will allow the effective analysis of issues in Albania related to agricultural production, resource allocation, risk, environmental quality, and land use.

Dr. Milto Hyso (left), former Director of the Agricultural Research Institute in Lushnja, Albania, and Ms. Pranvera Bekteshi, Meteorologist, Hydrometeorological Institute, Tirana, Albania, inspect an IFDC validation experiment for CERES wheat, which is designed to determine the response to increasing rates of nitrogen fertilizer.

During the past year, several activities have brought IFDC closer to fulfilling this goal. In collaboration with the Albanian Land Resources Institute and the World Soil Resources Division of the Natural Resources Conservation Service, U.S. Department of Agriculture (USDA), IFDC scientists constructed a soils map for Albania on a scale of 1:200,000 based on the USDA Soil Taxonomy (Figure 5). The extent of each of the principal soil orders is given in Table 6. Construction of the soils map was made possible following the field assessment and laboratory analysis of soil profiles from several benchmark sites. Although this initial soil survey has provided critical input for the crop models, it represents only a first approximation of the soil resources in Albania. Further sampling and the derivation of maps that define smaller areas are planned to obtain a more accurate accounting of soil variability.

Field experiments were carried out to test the accuracy of winter wheat and maize models in predicting yield response to nitrogen fertilizer. These experiments were conducted by Albanian scientists at the Agricultural University of Tirana and the Agricultural Research Institute in Lushnja. The experiments have proven valuable

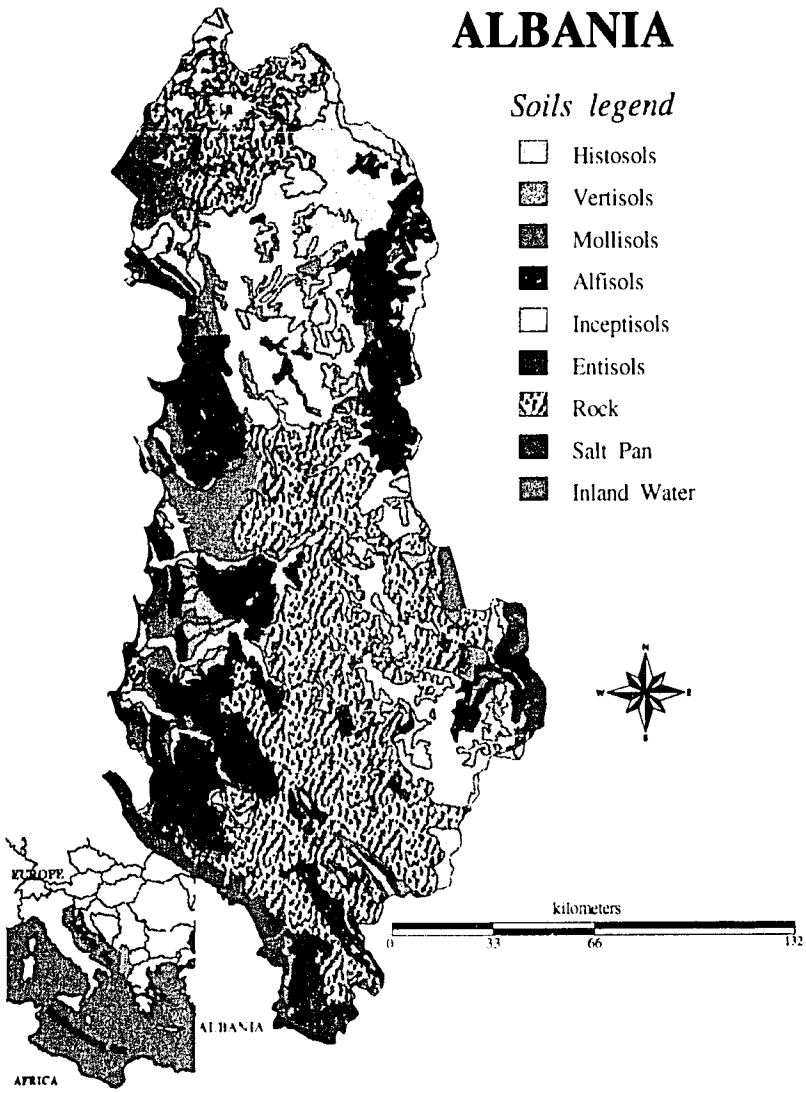


Figure 5. Soils Map for Albania (scale: 1:200,000).

for training Albanian professionals in the use of crop models, their data requirements, field generation of these data, and crop model application.

A training program was conducted at the Agricultural University of Tirana to introduce 23 Albanian professionals to systems analysis using crop simulation models. Two instructors from IFDC were assisted by four Albanian scientists who had previously received training in the use of crop models at IFDC Headquarters and the University of Florida. The participants in the training program came from several institutions, including the Agricultural University of Tirana, the Agricultural University of Korca, the Agricultural Research Institute in Lushnja, the Vegetable and Potato Research Institute in Tirana, the Institute for Soil Studies, the Hydrometeorology Institute, the Albanian Fertilizer and Agricultural Inputs Dealers Association (AFADA), and IFDC-Albania. The

Table 6. Extent of Major Soil Orders (USDA Soil Taxonomy) in Albania

Soil Order	Total Area (ha)
Histosols	3,978
Vertisols	58,542
Entisols	162,613
Mollisols	206,402
Alfisols	492,078
Inceptisols	995,951
Rock with shallow Inceptisols	716,838
Rock with shallow Entisols	95,219
Rock outcrops	50,769
Salt pans	4,056
Inland water	41,536

training program consisted of a combination of lectures and hands-on computing activities. After a basic introduction to computers, participants were taught how to (1) input, organize, and store data on crops, soils, and weather; (2) retrieve, analyze, and display data; (3) validate and calibrate crop growth models; (4) evaluate different management practices and genotypes at a given site; and (5) evaluate risk associated with weather variability. Participants in the training program have formed an informal network of collaborators that will support the development of management information systems to be used in policymaking, research, extension, and agribusiness activities.

This training course was designed to be the first of a number of in-country training activities that will support the Ministry of Agriculture's future plans for the development and application of management information systems. The institutionalizing of data collection techniques and the management of information are of great importance to the future of Albanian agriculture.

A famine early warning system for Burkina Faso

Predicting crop yields is inherently problematic because of the amount of uncertainty that prevails in any agricultural system. Yield forecasting is thus not concerned with a given endpoint but rather with a distribution of outcomes. In conjunction with the U.S. Agency for International Development (USAID) Famine Early Warning System (FEWS) project and the Earth Resources Observation Systems (EROS) Data Center, South Dakota, (U.S.A.), IFDC's systems scientists developed in 1994 a prototype system linking the CERES-Millet model with a GIS to make real-time projections for millet yields in Burkina Faso. The goal of the project is the development of a real-time yield forecasting system that will predict at the earliest possible time during the course of a growing season any significant deviation in long-term mean millet yields so that appropriate action can be taken. In a deficit situation, foodstuffs could be imported to alleviate shortages; in a surplus, plans for export or stockpiling of grains could be initiated.

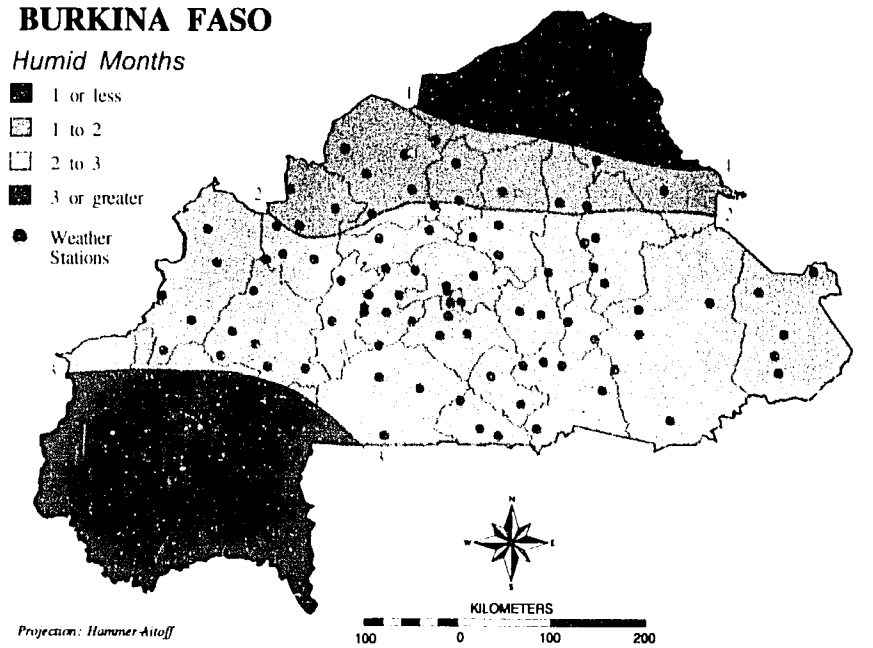


Figure 6. Map of Burkina Faso Showing the Major Agroclimatic Zones and the Location of the Weather Stations Used in the Study.

The prototype FEWS system for Burkina Faso links the CERES-Millet model with soil and weather databases. Spatial and climatic resources are interfaced through the GIS package, IDRISI. Soil resources were determined from the Agricultural Soil Suitability Map of Burkina Faso by the Office de la Recherche Scientifique et Technique de Outre-Mer (ORSTOM) at a scale of 1:500,000. Historical rainfall data for 231 sites (with at least 14 years of data) were available, and parameters for generating simulated weather were constructed (Figure 6). All coefficients were interpolated to a 0.25° latitude-longitude grid. Decadal (every ten days) satellite data images of cold cloud duration are available from the Climate Analysis Center of the National Oceanic and Atmospheric Administration (NOAA), which produces decadal rainfall estimates using computing algorithms developed at Reading University in the United Kingdom. Real-time rainfall estimates derived from cold cloud duration can then be combined with simulated weather to derive a series of outcomes for the millet-growing season. As more and more real weather becomes available and less probabilistically generated weather is used, millet production on a district basis can be estimated progressively with a corresponding decrease in the deviation of projected outcomes. The results of the simulations can be expressed as a percentage deviation from long-term mean production in each district.

Although the prototype system is functional, only limited testing has been done. The two major areas of validation that need to be addressed are:

1. Ground truth validation of rainfall estimates from the decadal satellite data;
2. Millet model calibration and validation using historical data for yield comparisons with government statistics.

To illustrate the way in which a yield distribution can be modified through a growing season, some simulations were carried out using CERES-Millet in Dori in northern Burkina Faso (average annual rainfall 470 mm). For all simulations, millet was assumed to be planted on day 160 (9 June); in this environment the crop can mature in about 100 days. Decadal totals were calculated for 1986 and 1990 from the historical rainfall records for Dori. For each year, the millet model was then run at 10-day intervals; these would correspond to "forecast" dates in the situation where the model was being run through the current growing season. Up to the day of forecast, decadal totals were used in lieu of satellite data. From the day of forecast onward, rainfall was simulated probabilistically until the end of the growing season. The results of simulations replicated 20 times for each of the 11 forecast dates are shown in Figure 7 for two contrasting years, 1986 and 1990. Yields are expressed relative to the mean of the yield distribution obtained when all the weather is generated probabilistically, corresponding to the preseason expectation of yield (i.e., when nothing is known about the current season). As the forecast date progressed, the mean simulated millet yield decreased in 1986 but increased in 1990 while the standard deviations of the yield distributions decreased in both years as the amount of probabilistic weather in the simulations decreased.

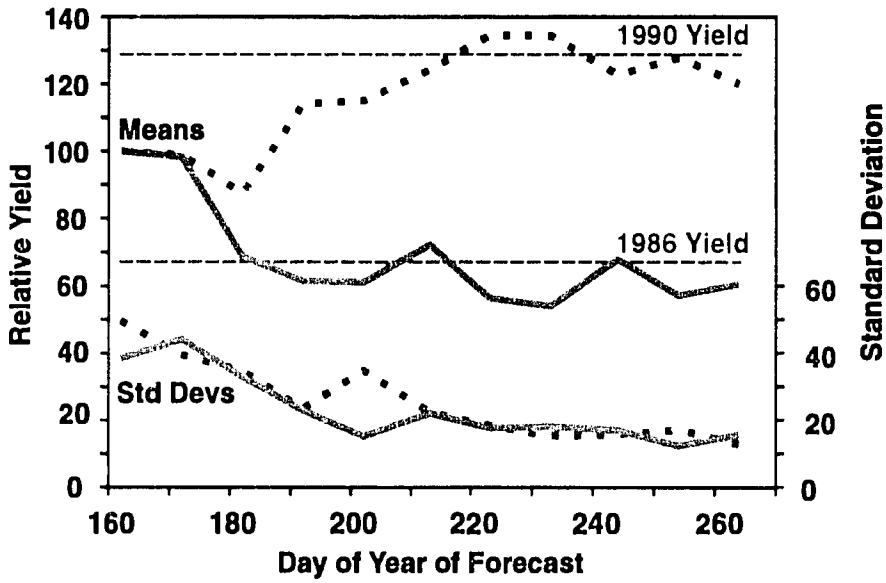


Figure 7. Simulated Millet Yield Distributions for Conditions in Dori, Burkina Faso, Derived at Various Forecast Dates Using Historical Decadal Rainfall Totals Up to the Day of Forecast and Probabilistic Weather Data Thereafter; 1986 (—) and 1990 (▪ ▪ ▪).

Rainfall at Dori in 1986 was 67% of the long-term average. In Seno, the district in which Dori is situated, the observed average district-wide yield of millet in 1986 was 237 kg/ha, compared with a long-term average from 1984 to 1992 of 352 kg/ha. The 1986 yield was thus only 67% of normal. The simulated yield deviation from normal agrees well with this value – final average yield at Dori was simulated to be about 70% of normal in 1986. From Figure 7, by the fourth forecast date (day 192), the forecast average deviation was already at the 60% level, giving early indications that the season was likely to be poor. This was indeed the case in 1986. In 1990, by contrast, rainfall was more plentiful although still less than average. The district average yield was 29% above the long-term average however (454 kg/ha). By day 213, the mean simulated millet yield was 20% above the average, giving a reasonably early indication that the season was going to be better than average.

The good agreement between simulated and observed yields for 1986 and 1990 in Dori and Seno Province is probably accidental. However, even if reasonably accurate indications of final yield could be given 4 to 6 weeks before crop maturity, this would still afford policymakers time to plan if catastrophic crop failure appeared possible. The inputs for driving the model are readily available electronically, the system is readily expandable to all at-risk areas, and the low-cost system runs on personal computers. The system could easily be made available to district government officers and policy analysts. IFDC plans to develop the prototype further in 1995 in conjunction with the new FEWS-3 project and the EROS Data Center and to initiate extensive testing.

Commercial/industrial information services

IFDC's Impact in Asia
The Malaysian Example

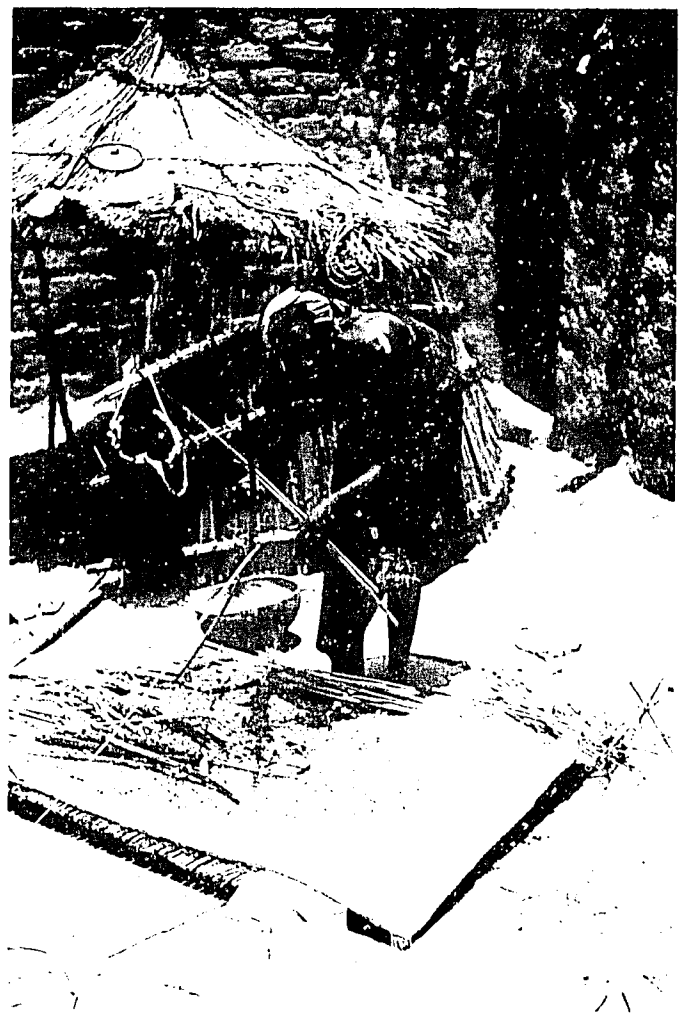
IFDC assisted in the construction of a Malaysian fertilizer company by coordinating with engineering firms and providing long-term startup assistance. IFDC helped the company realize a saving of about 30% on construction costs by assisting in managing the entire project and using local resources for all major equipment fabrication. IFDC staff also provided assistance in optimizing plant performance and product quality.

In 1994 IFDC contracted with The Fertilizer Institute (TFI) to compile and publish a number of statistical reports on the North American fertilizer industry. These reports were formerly prepared by the Tennessee Valley Authority (TVA). A number of reports were prepared for TFI in 1994. These include the monthly *Fertilizer Record*, which is released each month and includes information on current production, stocks, and disappearance by product during the previous month. The *Quarterly Producer Financial Report* and the *Quarterly Potash Financial Report* provide quarterly statistics relating to the company's finances. An operating rates report is completed twice a year. IFDC has also completed the (1) *Annual Production Cost Survey* that provides the cost of production for a number of products, including ammonia, phosphate rock, sulfuric acid, phosphoric acid, DAP, monoammonium phosphate (MAP), TSP and (2) the annual *Fertilizer Financial Facts* providing annual financial information that can be compared with results for the previous year. An annual "fertilizer record" is also prepared which, in addition to the data collected in the *Monthly Record*, includes statistics by product on the imports and exports by month for the United States and Canada. Revisions in the monthly data are incorporated before the annual data are published.

During 1994 IFDC began preparing the *North American Fertilizer Capacity* report, which was formerly produced by TVA. IFDC published updated versions of this report three times during 1994. Data on Mexico were added during 1994, and information on Trinidad will be added in 1995. An IFDC working group meets monthly to review changes that have taken place in capacity during the previous month.

At the request of TFI, IFDC prepared an environmental emissions study for nitrogen and phosphate plants in North America, which summarized various reports that have been prepared and submitted to the Environmental Protection Agency (EPA) since 1987. During 1994 IFDC also participated in two fertilizer price and consumption surveys, in which respondents estimated changes expected in fertilizer prices during the first half of 1995. Respondents also estimated changes in consumption that were expected during 1994 compared with 1993 and the major factors expected to influence prices and consumption. Respondents were also asked to provide current farm-level fertilizer and crop prices. Approximately 50 companies from 35 countries participated in this survey. IFDC is also cooperating in a joint report on *Fertilizer Use By Crop*, which is published every two years by the International Fertilizer Industry Association (IFA), the Food and Agriculture Organization of the United Nations (FAO), and IFDC. Updated information in 1994 was received from about 50 countries; thus, about 100 countries are now reporting on rates of fertilizer application by crop. A report was published in late 1992, and a new report was produced in late 1994. IFDC publishes a number of other reports that provide statistical information on fertilizer, including the "Asia Fertilizer Situation," "Africa Fertilizer Situation," "Latin America Fertilizer Situation," and "Eastern Europe Fertilizer Situation." These reports contain a number of graphs and tables that depict the trends occurring in those regions of the world and individual supply/demand summaries by country.

Global Fertilizer Policy Research



Efficient, equitable, and environmentally friendly use of fertilizers depends on a three-pronged strategy based on sound agronomic practices, appropriate fertilizer products, and an enabling policy environment. In many developing countries, distorted and unstable policies have created a nonconducive environment for the adoption of agricultural technologies and have therefore prevented these countries from becoming food secure. Technology and policy are two indispensable legs needed for a march towards sustainable food security and environmental protection. Developing one without the other can only result in suboptimal developments. Consequently, IFDC is constantly involved in pursuing policy research.

Global fertilizer perspective, 1980-2000

Recent changes in Eastern Europe and the former Soviet Union have brought on uncertainty in the agricultural and fertilizer sectors. In addition, the world is facing many other challenges such as sustainable development, environmental protection, food security, and global warming. All of these developments affect fertilizer sector operations directly and indirectly.

The United Nations population projections indicate that world population will increase from 5.5 billion in 1993 to 6.3 billion in the year 2000, 8.5 billion in 2025, and 10.0 billion in 2050. Over 95% of the growth in world population between 1990 and 2050 will occur in Africa, Latin America, and Asia, where nearly 1 billion people already suffer from poverty, hunger, and malnutrition. Such unprecedented growth in population mandates that food production be increased to feed an additional 3 billion people – equivalent to the 1960 world population – by 2025 and a little less than 5 billion people by 2050. In addition, a recent United Nations study estimated that about 10.5% of the planet's most productive soil (1.2 billion ha), an area the size of China and India combined, has been damaged. Over three-fourths of that degradation has occurred in the developing countries. Thus, the challenge of feeding the growing population must be met by restoring the degraded soils and preserving the resource base. In meeting both of these challenges, fertilizers have an important role for two reasons. First, they facilitate the adoption of yield-increasing technologies and thereby promote sustainable growth of food production on limited cultivable land. Second, they help to replenish nutrients removed by crops and therefore prevent soil degradation and preserve the resource base.

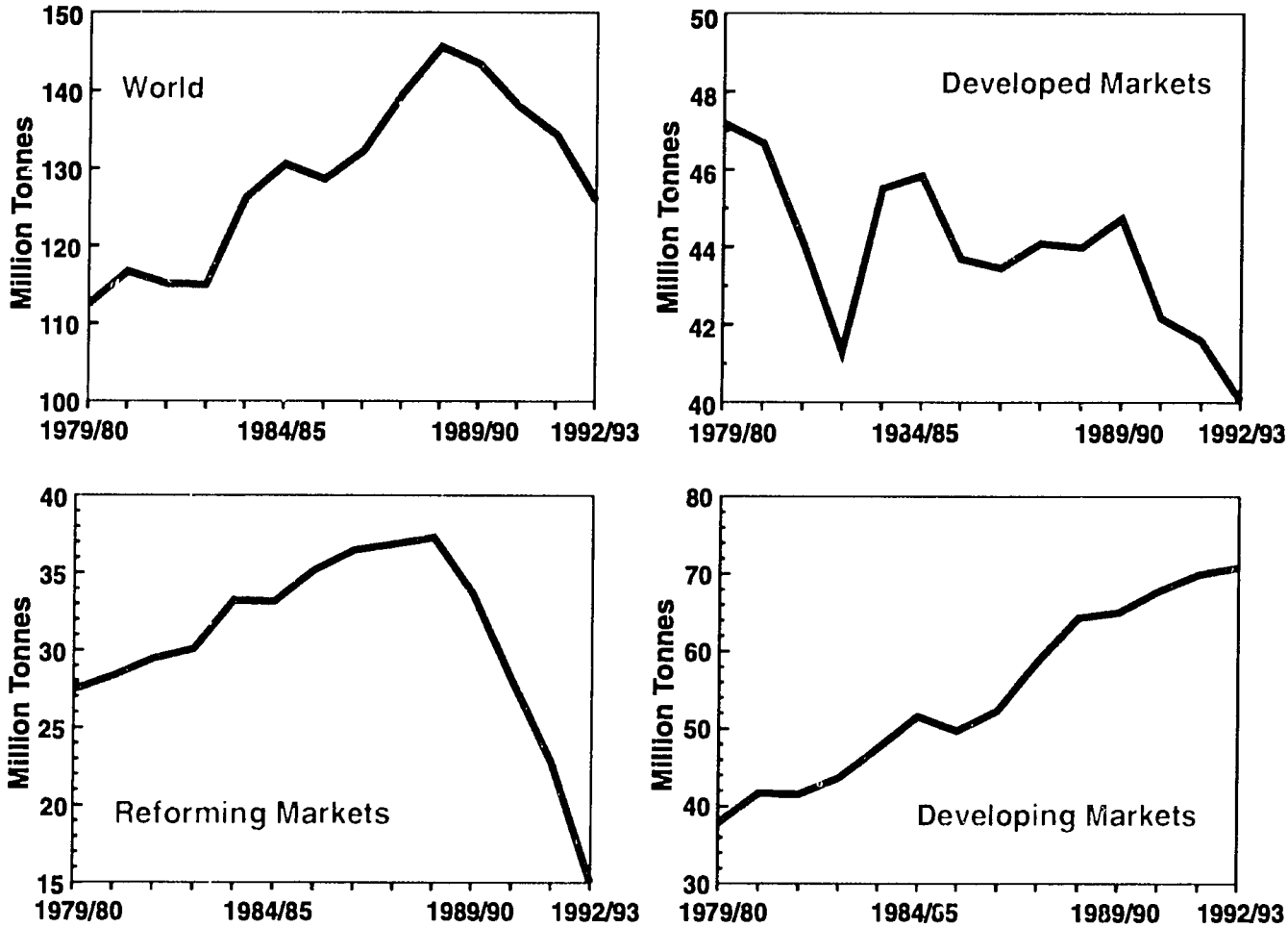
Against this background, IFDC completed a study, entitled *Global Fertilizer Perspective, 1980-2000: The Challenges in Structural Transformation*. The study analyzes the trends in fertilizer use, production, and trade during the 1979/80 to 1992/93 period and provides projections for fertilizer demand, supply, and supply/demand balances during the 1993/94 to 2000 period. It also assesses the impact of the projected growth in fertilizer use on food security and environmental protection and makes necessary recommendations to meet these challenges in the 1990s and beyond.

Fertilizer Trends

Global fertilizer use increased from 112.5 million tonnes in 1979/80 to 145.6 million tonnes in 1988/89. After 1988/89 it decreased continuously to reach 125.9 million tonnes in 1992/93 (Figure 8). Most of the decrease in global fertilizer use between 1988/89 and 1992/93 was due to a steep decline in fertilizer use in the reforming markets. Changes introduced under economic and political reforms have led to the collapse of the fertilizer markets in these regions. Fertilizer use also decreased steadily in the developed markets but increased significantly in the developing markets. Western Europe contributed most to the trends in the developed markets, Eurasia (newly independent states of the former Soviet Union) in the reforming markets, and Asia in the developing markets. In addition to economic and political reforms, structural adjustment programs, foreign exchange shortages, depressed crop prices, environmental concerns, and agronomic factors contributed to recent decreases in fertilizer use.

Following the trends in fertilizer use, global fertilizer production increased from 118.7 million tonnes in 1979/80 to 158.3 million tonnes in 1988/89 and then decreased by 20 million tonnes to reach 138.3 million tonnes in 1992/93. The decline in production in the reforming markets was a major contributing factor to the fall in global fertilizer production. Decreased demand, unremunerative and low fertilizer prices, and environmental regulations also adversely affected fertilizer production. Only North America, Africa, and Asia recorded growth in fertilizer production during the early 1990s.

Global fertilizer imports increased by 4%/year during the 1980-89 period but stagnated



Note: The developed markets include North America, Western Europe, and Oceania; the reforming markets include Eastern Europe and Eurasia; and the developing markets consist of Africa, Asia, and Latin America.

Source: Derived from FAO data.

Figure 8. Global Fertilizer Use by Markets, 1979/80 - 1992/93.

thereafter. Both the developed and the reforming markets remained net exporters; whereas, the developing markets were net importers. In the developing markets, net fertilizer imports increased from 10.5 million tonnes in 1979/80 to 17.0 million tonnes in 1992/93. Only North Africa and West Asia were net exporters; all other developing regions were net importers.

Slow growth in demand and excessive surpluses have kept fertilizer prices rather low and at unremunerative levels in the global market. Nevertheless, due to devaluation and subsidy removal, fertilizer prices in domestic markets increased severalfold in many developing countries.

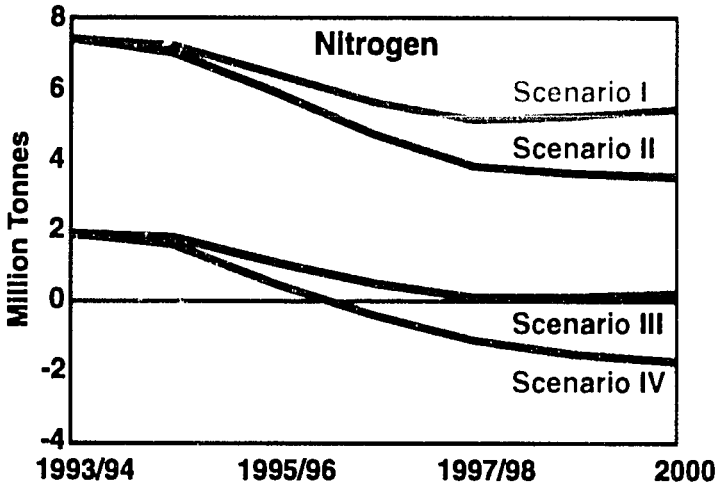
Future Outlook

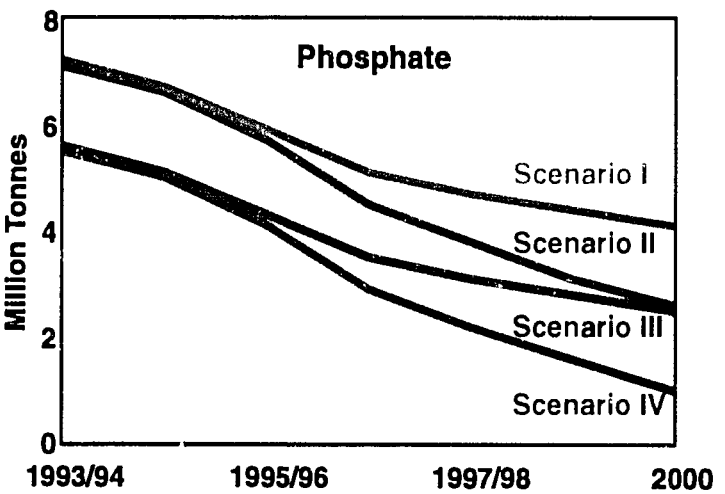
Global fertilizer use is projected to increase from 125.9 million tonnes in 1992/93 to 142.6 million tonnes under Scenario I and 147.3 million tonnes under Scenario II in the year 2000. Under Scenario II a slightly higher growth in fertilizer demand is projected for Eastern Europe and Eurasia. Only under Scenario II will global fertilizer use be marginally higher than it was in 1988/89. Thus, global fertilizer use is expected to have a "roller coaster" ride in the 1990s. Nitrogen, phosphate, and potash use is projected to increase from 73.6, 31.5, and 20.8 million tonnes, respectively, in 1992/93 to 81.3, 37.3, and 23.9 million tonnes under Scenario I and 83.2, 38.9, and 25.2 million

tonnes under Scenario II in the year 2000. A gradual decline in fertilizer use in the developed markets and a slow recovery in the reforming markets are responsible for little growth in global fertilizer use during the 1990s. However, fertilizer use in the developing markets is expected to increase by about 14 million tonnes. Asia will account for 74% of the increase in fertilizer use in these markets.

Ammonia, phosphoric acid, and potash production capacities are expected to increase from 116.8, 36.5, and 36.7 million tonnes, respectively, in 1992/93 to 127.9, 40.4, and 39.2 million tonnes, respectively, in 2000. Excessive surpluses and depressed prices are responsible for modest increases in phosphoric acid and potash capacities. Two scenarios are also developed for estimating fertilizer supply potential. One scenario assumes moderate operating rates and the other low operating rates for Eastern Europe and Eurasia. The main rationale for the second scenario is that a relatively higher closure of capacity may occur because of low demand and financial difficulties and therefore a lower supply may be available in the future.

Nitrogen supply potential is projected to increase from 79.4 million tonnes of nitrogen in 1992/93 to 86.7 million tonnes of nitrogen under Scenario I and 81.3 million tonnes of nitrogen under Scenario II in the year 2000. Phosphate and potash potentials are expected to increase by modest amounts under Scenario I, whereas under Scenario II, potash supply may decrease by about 1 million tonnes in the year 2000.





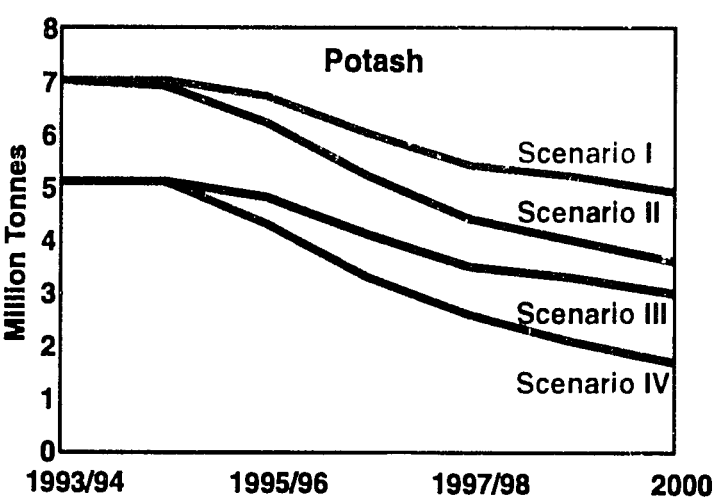


Figure 9. World: Fertilizer Supply-Demand Balances, 1993/94 - 2000.

Because of slow growth in demand and existing surpluses in the markets, the projected supply/demand balances show considerable surpluses for all three nutrients. Two scenarios each for demand and supply projections yield four scenarios for estimating supply/demand balances. Scenarios I and II combine moderate operating rates with low and moderate growth in fertilizer demand, whereas Scenarios III and IV embody low operating rates with low and moderate growth in demand. These surpluses will range between 4 and 7 million tonnes of nutrients under Scenario I (Figure 9). Under Scenarios II and III, the magnitudes of these surpluses are reduced considerably for phosphate and potash and become insignificant for nitrogen after 1996/97; only under Scenario IV will nitrogen shortages develop after 1995/96. However, it is unlikely that this scenario will materialize. Thus, fertilizer shortages are unlikely to constrain fertilizer use in the 1990s.

Table 7. Food Production and Fertilizer Use in the Developing Markets, 1990-2000

Projected growth in fertilizer use	19.5 million tonnes
Additional grain production[a]	136.8 million tonnes
Additional number of persons likely to be fed by additional grain production[b]	456 million
Population growth[c]	915 million
Additional food-insecure people[d]	459 million

a. Assuming that 70% of the projected growth in fertilizer use will be applied to grain crops and each additional tonne of fertilizer nutrient yields 10 additional tonnes of grain output.
b. Based on the assumption that 300 kg of grain is needed to provide adequate nutrition to one person/year.
c. U.N. population projections.
d. Additional people receiving inadequate food supply.

Food Security

In the developing markets, food security is a *chronic* problem. Nearly 1 billion people live under the conditions of hunger and malnutrition. The projected growth in fertilizer use in these markets is inadequate to meet the challenges of feeding the growing population (Table 7). Unless new programs and policies are implemented to accelerate grain production through efficient and environmentally sound fertilizer use and other related measures, the world may face more hunger and malnutrition and environmental degradation at the turn of the century than it is facing now.

Policy Recommendations

In order to meet the challenges of feeding the growing population and preserving the natural resource base, fertilizer use should be promoted in those countries where fertilizer use levels are low and food insecurity and environmental degradation are serious problems. However, growth in fertilizer use should be efficient, equitable, and environmentally sound.

The evidence from several developing and reforming countries suggests that a conducive and stable policy environment is essential to promote efficient, equitable, and environmentally sound fertilizer use and production; policymakers should therefore pay special attention to creating such environments. Depending on the initial conditions and the degree of government involvement, the simultaneous introduction of some policies, such as devaluation, subsidy removal, and the sudden withdrawal of government from the fertilizer sector operations, can lead to the collapse of the fertilizer markets. Proper sequencing and phasing of policy reforms are essential.

Because most of the fertilizer surpluses are concentrated in the developed and reforming markets, the developing markets should prepare optimal strategies to benefit from such favorable conditions and yet protect against the uncertainty associated with conditions in the reforming markets.

Policy Reform, Market Research and Development in West Africa

In sub-Saharan Africa IFDC continues to emphasize the importance of implementing policies that encourage increased fertilizer use. Toward this end, IFDC works in concert with national institutions to develop cost-effective fertilizer marketing strategies by collecting, analyzing, and disseminating data on fertilizer production, marketing, and use; by conducting detailed studies of the fertilizer sectors of individual countries; and by collecting economic, agronomic, and technological data, which is entered into a database that is available to West African countries.

Policy Reform, Market Research and Development in West Africa

A fertilizer privatization plan for Ghana

The future of Africa rests in the hands of children like these from Ghana.

The Government of Ghana requested IFDC-Africa to conduct a study to find ways to reduce farmers' fertilizer costs, which increased sharply following adoption of privatization measures. Obviously an increase in fertilizer prices relative to crop prices discourages farmers to use more fertilizers and jeopardizes privatization of the fertilizer sector. The study identified various options, which are aimed at reducing the cost of fertilizers, increasing returns to farmers from fertilizer use, and increasing consumption of fertilizers by Ghanaian farmers.

The study was jointly undertaken by IFDC-Africa and the Policy Planning, Monitoring and Evaluation Department of the Ministry of Food and Agriculture. The study enlisted the services of local consultants and established a fertilizer marketing advisory committee to monitor progress of the study.

Representatives of the private fertilizer sector, the Ministry of Food and Agriculture, and the University of Ghana worked as local consultants on the study. The participation of local consultants strengthened the national capacity to conduct such sector studies and ensured that the recommendations and conclusions include the opinions of national experts. Secondly, a fertilizer marketing advisory committee, which was formed to monitor the study's progress, allowed the exchange of ideas between all those involved in the fertilizer privatization scheme.

The Government phased out fertilizer subsidies from about 45% in the mid-1980s to 0% in 1992. Fertilizer importation and distribution functions by the state were transferred to the private sector in 1988. In 1994 one private importer acquired the lion's share of the market.

During 1992-94 fertilizer import prices increased threefold. After the removal of subsidies, the impact of persistent devaluations was fully charged to farmers. In 1994, fertilizer retail prices amounted to Cedis 17,500/50-kg bag of 20-20-0; whereas, a 50-kg bag of maize was valued at only Cedis 6,000 on the wholesale market. At these prices, farmers are not compensated for the costs of fertilizers, nor are they compensated for extra work and risks associated with fertilizer use. As a result, farmers' demand for fertilizers decreased from about 40,000 product tonnes in the late-1980s to 11,600 tonnes in 1994, and fertilizer traders are currently

having difficulties recovering their capital that is committed to fertilizer trade.

Analysis of fertilizer marketing costs and margins revealed that import costs are the most important determinant of fertilizer costs, estimated at 57% in 1993; the more probable figure for 1994 is 60%-70%. Fertilizer import costs are especially high because importers procure small quantities of relatively expensive fertilizer products from a restricted number of suppliers overseas. A Government-prepared fertilizer import list, which provided explicit product and quality guidelines to fertilizer importers, has proved to be a restriction on the development of a competitive fertilizer market in Ghana.

Basal fertilizers on the Ghanaian fertilizer market are nitrophosphates (nitric acid-based NPKs), which are conventional fertilizers in Western Europe but not in the rest of the world. Ghanaian farmers primarily use ammonium sulfate (AS) as a topdressing material. This is a very expensive source of nitrogen, and it has an immediate acidifying effect, especially on poorly buffered soils.

In terms of fertilizer nutrients, compound fertilizers (NPKs) imported into Ghana were twice as expensive as DAP imported into neighboring Côte d'Ivoire. DAP can be used directly in agriculture (rainfed and irrigated foodcrops) or mixed with other ingredients, such as urea, AS, and muriate of potash to produce a blended fertilizer. Abidjan, capital of Côte d'Ivoire, has a blending facility and benefits from economies of scale for bulk transport and competitive procurement of blending ingredients, including DAP.

In recent years, the Ghana cotton sector has been growing steadily. Some believe that the cotton area could double in the next 10 years if ginning capacity is increased. The Ghanaian cotton sector primarily uses NPKs and AS; whereas, francophone Africa uses a compound enriched with sulfur and borax, with urea as topdressing material.

The costs of cotton fertilizers can be significantly reduced if Ghanaian importers jointly procure fertilizers with Société Burkinabe des Fibres et Textiles (SOFITEX), a cotton organization in Burkina Faso. SOFITEX is willing to increase its requirements of the cotton fertilizer if a Ghanaian importer will join in the tender, which is certain to result in price discounts. The tender could stipulate quotation, c.i.f., Tema or, c.i.f., Abidjan for destinations in northern Ghana and Burkina Faso. Joint importation can only be an alternative if the Government allows a nitrate-free product and blends. SOFITEX does not recommend nitrate nitrogen and requests all nitrogen in the ammonia form. Burkina Faso farmers have accepted the more cost-effective blended form of the cotton fertilizer.

Following import costs, financial charges are the second highest cost-determinant amounting to 14% of fertilizer costs. The annual interest rate amounted to 19%-23% for a loan or overdraft, and bank charges such as processing and document negotiation fees may amount to 4% of the value of the Letter of Credit. Given the high-risk and low-profit nature of the fertilizer business, banks are reluctant to provide credit for private sector fertilizer trade. Fertilizer importers have difficulties in meeting the minimum required loan conditions and often resort to donor-established guarantee-funds, which only marginally reduce the banks' reluctance. This reluctance by banks often makes it impossible for Ghanaian importers to take advantage of quick buying opportunities that may offer lower prices. It should be noted that cost of financing is of minor importance compared to the accessibility of bank credit, which is a basic condition for private fertilizer trade.

Total terrestrial, long-distance transportation costs constitute about 5%-15% of the costs of fertilizer in Ghana. The cost of fertilizer is greatly influenced by distance, availability of return cargo, and volume of fertilizer transported. However, considering that terrestrial transport costs are a relatively small part of total costs, optimization can have only a limited effect on the total cost of nutrients.

At the retail end, the transfer to the private sector is still in transition. There are no private dealers in the regions where the public Farmers Services Companies (FASCOMs) are operating. The prognosis for both the FASCOM (Upper Region), Ltd., and FASCOM (Volta Region), Ltd., in a privatized fertilizer market is not very encouraging; activities at the FASCOMs have dropped to their lowest ebb because of capital shortage, large outstanding debts, and relatively high overhead costs.

Fertilizer sector study in Mali

As part of the fertilizer marketing studies, IFDC-Africa conducts country studies to identify the constraints related to the fertilizer sector and provide recommendations for a more efficient use of plant nutrients to enhance food security.

The Mali study, which was conducted during 1993/94, will be published in 1995. Reflecting the Malians' concerns, five themes were developed in the study and included liberalization/decentralization of the fertilizer market, impact of FCFA devaluation on inputs and agricultural production, evaluation of imported fertilizers, acceptance of Tilemsi phosphate rock (TPR), and analysis of alternative sources of plant nutrients. A team composed of Mali's Institut d'Economie Rural (IER) and IFDC-Africa's researchers worked together on the different themes, and a steering committee, composed of members of the public and private fertilizer sector, was established to follow the study and act as resource persons. The direct involvement of Malian partners in the study through IER researchers and the steering committee is expected to facilitate the implementation of the study's recommendations and contribute to strengthening the national capacity in the fertilizer sector by training national collaborators.

The Malian fertilizer market is basically dominated by areas with well-developed extension systems and other farmers' services such as Compagnie Malienne pour le Developpement des Textiles (CMDT), Office du Niger, and Office de la Haute Vallée du Niger. In these zones, cotton – a major crop controlled by CMDT – a parastatal company, accounts for about 81% of total fertilizer consumption.

The primary fertilizer products used in Mali are 14-22-12 SB, 15-15-15, urea, and DAP. In the noncotton zones (Office du Niger, for example), private sector involvement in fertilizer procurement and distribution is well established. In these areas, farmers have established associations, which order their inputs directly from private enterprises through banks.

As is the case in other African countries, privatization has become

IFDC's Impact in Africa
The AFTMIN Example

IFDC's market development project in West Africa has made remarkable strides since its inception in 1987. As a result of this project, the West African fertilizer market is more transparent. The monthly African Fertilizer Market bulletin is distributed in English and French to 228 individuals in 52 countries. Seven annual meetings have been conducted with the number of delegates tripling since 1988. In-depth fertilizer sector studies have been carried out throughout West Africa; these included both country-specific and thematic studies dealing with bulk-blending, privatization, and the use of phosphate rock. An African Fertilizer Information Database, which has been established, contains national fertilizer supply and demand statistics, national fertilizer prices, and fertilizer trade information on the sub-Saharan fertilizer market. Alternative fertilizer policy and marketing strategies have been identified; each has the goal of developing sustainable agricultural production systems.

a key issue in Mali; however, a gap exists as far as private sector involvement in the agricultural input distribution is concerned.

National currencies of all West African countries have been devalued, and this has made imported fertilizers and raw materials for the production of fertilizers more expensive. With the devaluation of FCFA by 50% on January 12, 1994, the governments of francophone West African countries increased prices of cotton to compensate for the increased fertilizer prices. The inputs supply and output marketing of cotton are in the hands of parastatal organizations.

The recent devaluation in francophone countries have had two major effects on the agriculture sectors:

1. An increase in the return to farmers from fertilizer use on export crops (for example, coffee and cotton) and on crops such as irrigated rice. The study focused on the impact of devaluation on the cotton, rice, and maize sectors. For Mali, during the present agricultural campaign, the devaluation has had a positive impact in terms of the growth rate of gross margin – 37% for cotton, 67% for irrigated rice, and 22% for maize in the south.

2. Increased competitiveness of domestic production with imported products such as rice (Mali and Senegal). The overvaluation of the FCFA has always been considered one of the most important factors affecting competitiveness of the agricultural products of francophone countries.

If the return from fertilizer use is not positive, fertilizer use on nonirrigated foodcrops may stagnate or be reduced after devaluation.

For imported fertilizer, the focus was on the following three concerns: (1) the high price of imported fertilizers and the rigidity of fertilizer grades and specifications that can influence the price; (2) a single recommendation per crop for the whole country; (3) the effect of liberalization and privatization on quality control of fertilizers.

Analysis of collected data indicated that there is no justification for requiring 100% water-solubility of phosphate, an ammonium-nitrogen form, and complex fertilizers. These restrictions limit the product choice that could cover the nutrient demand. The countrywide fertilizer recommendations and fertilizer types, which were established 15-20 years ago, do not cover the present nutrient needs. The fertilizer recommendations need to be modified, considering factors such as land use, agricultural equipment, and potential yields. A fertilizer quality control system needs to be implemented to avoid the supply of adulterated, substandard fertilizers.

The study indicates that TPR gives excellent results in its actual form in slightly acid soils, under semihumid conditions, and on the fallow preceding the rotation. Farmers were forced to use TPR in addition to the regularly recommended fertilizers; thus, their production costs rather than the benefits were increased. The extension workers who promoted TPR were not well informed on TPR's characteristics.

Research on the direct application of TPR has been conducted for several years. Favorable crop responses were found for TPR application; however, farmers' acceptance is low because of its costs, physical appearance, and a lack of extension.

An inventory was conducted of the available agroindustrial byproducts, organic wastes, and local mineral sources that could be used as nutrients to complete and then to reduce quantities of the expensive imported fertilizers. The identified products consisted of byproducts from the cotton, sugarcane, and rice industries, slaughterhouses, city and household wastes, calcareous and phosphate sources. Competitive uses (animal feed and household needs) were found for byproducts from the cotton and rice industry and slaughterhouses.

Privatization of the Nigerian fertilizer sector

In 1994 the Federal Ministry of Agriculture of Nigeria commissioned IFDC to develop a plan for the liberalization of the Nigerian fertilizer sector to encourage private sector participation and, thus, improve efficiency and make fertilizer readily available to farmers at the right time, place, and price. The approach is to withdraw the subsidy over a period of time and to transfer the responsibility for fertilizer procurement and marketing wholly to the private sector, while the Government retains regulatory responsibility and establishes institutional control and support systems required for a liberalized sector. A team of IFDC and Nigerian scientists conducted the study that recommended liberalization and gradual reduction of the subsidy. The Government of Nigeria will change its role from supplier of goods and services to protector of farmers' and traders' interests and the environment.

Today, fertilizer procurement and distribution remain a statutory monopoly of the Federal Government of Nigeria. For almost two decades, Government's direct involvement in the fertilizer sector has been plagued by a complex set of marketing, logistical, and administrative problems that have restricted agricultural growth, national food security, environmental preservation, and the national budget.

Government monopoly of fertilizer procurement and distribution has prevented private sector participation and development of transparent, open, and competitive fertilizer markets. The high rate of subsidy on fertilizers (80%-90%) has induced losses, wastage, and market distortions, such as artificial demand, scarcities, excessive traders' profits, and cost markups. Small farmers, the intended beneficiaries of the fertilizer subsidy program, have limited access to the highly subsidized fertilizers. Fertilizer producers and middlemen are the main beneficiaries of the current system while the Nigerian Government is burdened with colossal and unsustainable subsidy expenditures, which amounted to Naira 8.9 billion (US$ 400 million at the official exchange rate) in 1994. At current and projected levels of demand in Nigeria, fertilizer subsidy will be a major constraint not only to agricultural development but also to other national development programs.

Entrepreneurial Capacity

Extensive field surveys revealed that considerable entrepreneurial capacity exists in Nigeria's agri-input market to generate the needed investment in the fertilizer business at the importation, wholesale, and retail levels. These organizations show enthusiastic willingness to enter the fertilizer marketing system, provided the Government establishes all the necessary support mechanisms and creates an environment for successful liberalization. Most of these firms and institutions have the organizational, management, procurement, importation, and marketing expertise to undertake the procurement and marketing of fertilizer to Nigerian farmers. They have access to international finance and the international market, long-term relations with the Nigerian banking system, and much experience in marketing products to farmers and rural consumers. If the Government decides to privatize the supply and marketing of this product, it will find a significant untapped capacity and resources.

Because of the numerous firms with great potential for fertilizer trade, a selection procedure would need to be devised for private sector participation in fertilizer importation using as the criteria – financial strength, marketing experience/distribution networks, management expertise, importation experience, desire, and performance in fertilizer wholesaling in 1995.

Policy Decisions

To liberalize the fertilizer sector, four policy changes must be made. Fertilizer trade covering importation,

wholesaling, and retailing will be in the hands of the private sector. Following full-scale liberalization (after the subsidy has been removed), fertilizer prices will be decontrolled and, therefore, determined by market forces. In addition, all controls prohibiting free trade in fertilizer will be removed. Fertilizer subsidy will be progressively reduced in 3 years at a rate consistent with Government finances and economics of fertilizer use. Government's role will be limited to policy formulation and legislation, quality control, product specifications, monitoring and evaluation, research and development, operations of buffer-stock, and establishment of an appropriate organ to manage subsidy and fertilizer foreign exchange funds.

Fertilizer marketing in Niger: Impact of the Nigerian policy

During 1994 IFDC completed and published a study entitled "The Marketing of Fertilizers in Niger: The Impact of the Nigerian Policy." Highly subsidized fertilizers from Nigeria comprise 70%-80% of the market in Niger. Farmers, and therefore food security, in Niger are highly vulnerable to the fertilizer policy in Nigeria. In general, Niger's situation is similar to that prevailing in the entire Sudano-Sahelian zone where pressures on both arable and grazing land are associated with a decline in soil fertility. To decrease soil degradation, measures must be taken to decrease nutrient losses, e.g., controlling erosion, incorporating crop residues and increasing inputs, e.g., greater use of manure, indigenous phosphates, and chemical fertilizer. These measures permit agricultural intensification; however, they represent significant investments for the farmers and can be undertaken over only a small area.

Table 8. Fertilizer Demand Estimates in Niger According to the Major Types of Fertilizer and Cultures

Types	Urea	15-15-15	Superphosphate	Total
			(tonnes)	
Irrigated	3,324	3,066	53	6,443
Off-season	1,284	1,431	-	2,715
Rainfed[a]	5,700	5,700	2,000	13,400
Total	**10,308**	**10,197**	**2,053**	**22,558**

a. The variable component of the demand on rainfed crops was not taken into consideration.

Fertilizer Use in Niger

In 1990 fertilizer use in Niger amounted to 22,600 tonnes. Table 8 shows demand according to three types of farming systems – irrigated farming, off-season farming, and rainfed farming – and the major types of fertilizer used. Urea and NPK each accounted for 45% of the demand, and the remaining 10% represented the demand for TSP and SSP applied in double doses.

Fertilizer Supply in Niger

In 1990 the Procurement Unit (Centrale d'Approvisionnement, C.A.) supplied 17%, and the private sector supplied 83% of the fertilizer used. The private sector meets 95%-99% of the demand in the southern parts of the Maradi and Zinder regions. The private sector's large share is due to the proximity of the Nigerian border and the distance from the capital, to which donor-supplied fertilizers to the Procurement Unit (C.A.) are delivered.

Private Fertilizer Trade From Nigeria

Of the 22,600 tonnes of fertilizer imported by Niger in 1990, roughly 3,800 tonnes was imported

by the parastatal sector. The private sector imported 18,800 tonnes from Nigeria. Of this total, 16,080 tonnes was imported by licensed private sector businessmen and at least 2,720 tonnes by small-scale businessmen or by the farmers themselves; between 5,000 and 10,000 tonnes of fertilizer is transported yearly from Nigeria through Niger to Mali and Burkina Faso.

Impact on Nigeria of Fertilizer Trade With Niger

Nigerian fertilizer producers do not have to create their markets since all production is sold to the Government at a fixed price, a price which is often higher than the import price. Import prices are high because there is little competition in the import market. Moreover, imported fertilizers are not controlled with respect to quality. Fertilizer subsidies amount to 80%-90% of fertilizer costs, and fertilizer prices are extremely low. Private fertilizer trade, although not allowed, flourishes within Nigeria and between Nigeria and neighboring countries, such as Niger.

The fertilizer traded from Nigeria to Niger is relatively insignificant; it constitutes only 1% of total fertilizer supply in Nigeria. However, this relatively small quantity is sold at high profits. Nigerian fertilizers are usually sold in Niger for much higher prices than the official price in Nigeria. Actually, large-scale merchants are benefiting immensely from the Nigerian fertilizer subsidy. The beneficiaries from these transactions are private traders.

Creating an Enabling Environment for Sustainable Agricultural Production in Nigeria and Niger

Liberalizing trade between Nigeria and Niger will increase competition, reduce marketing costs, and contribute to both economies. Free trade will reduce marketing costs – an advantage to the buyer and the seller. Farmers from Niger will sell more agricultural products to Nigeria for better prices, and Nigerian consumers will benefit from a larger supply and lower consumer prices. Nigerian traders will obtain the necessary foreign exchange by legally exporting fertilizers to Niger. Farmers in Niger will benefit from more competition, and fertilizer retail prices will be lowered. Nigerian fertilizers will be used again to produce more agricultural products at lower costs.

In Nigeria, reforms cannot be effective unless some structural changes are introduced in the fertilizer sector. The development of an integrated plan to reduce fertilizer market distortions and government expenditures within the fertilizer sector may benefit from the following considerations:

- Reducing fertilizer subsidy burden – First, a very low official farmgate price is not important to small farmers if they cannot find fertilizers in the sales outlet. Second, setting prices based on actual production costs will probably lower factory-gate prices and increase production efficiency and sales services.
- Creating competition in fertilizer markets – Recognizing and supporting the private fertilizer dealer through enabling policies will help develop a more open and competitive fertilizer market system, thereby improving services to small farmers. The current monopoly in the fertilizer import market prevents the reduction of import costs and improvements in import efficiency. This calls for market liberalization and a phased introduction of private-sector involvement in fertilizer importation. Private fertilizer importers can benefit from economies of scale, from purchase of fertilizers on spot markets when fertilizers are in excess supply in the world market, and from extended credit facilities offered by international fertilizer manufacturers and traders. Liberalization would also allow importation of a wider variety of fertilizer grades.
- Redefining Government's role in the fertilizer sector – As the policy environment becomes more favorable for increased involvement in the fertilizer sector, the Government could monitor the market; enact legislation; effect quality control; and formulate policy regarding supply, marketing, pricing and subsidy, research and extension, and environmental and other fertilizer-related issues.

Development of Soil Fertility Restoration and Maintenance Strategies in Niger and Nigeria

Both Niger and Nigeria have local phosphate rock deposits and

extensive areas where the lack of phosphorus severely limits food production. In many parts of Niger and northern Nigeria, phosphorus deficiencies have reduced vegetative growth, which in turn has promoted soil erosion and the physical deterioration of the soils. Local phosphate rock resources can be used to increase the phosphorus fertility of the soils, promote the establishment of vegetation, reduce soil loss through erosion, and increase crop yields.

To ensure that an adequate strategy is developed to improve the production base of the soil, a national Soil Fertility Management Unit (SFMU) needs to be established. The functions of the SFMU could include:

- Formulation of a set of integrated soil fertility restoration and maintenance strategies;
- Implementation and monitoring of a sustainable agricultural production program;
- Collection, management, analysis, and dissemination of market information;
- Development and introduction of adequate input legislation, and monitoring of product quality; and
- Provision of policy and expert advice and research guidance.

Privatization of Farm-Input Marketing Systems

Carefully structured policy reforms that create incentives for agricultural production and promote international competitiveness of various farm inputs and commodities help to make agriculture a more cost-effective enterprise and enhance its contribution to the economic advancement of nations. Developing-country governments continue to turn to IFDC for sound, impartial advice as they establish the necessary institutions and infrastructure to support open, competitive markets. During 1994 IFDC's agribusiness component continued to meet with singular successes in Albania, Bangladesh, and Venezuela.

Albania

IFDC's Impact in Eastern Europe The Albanian Example

IFDC has assisted the Government of Albania in establishing a free market economy in that country's agricultural sector. The IFDC project created a fully privatized market for agricultural inputs, developed a supporting institutional capability, and nurtured the development of the Albanian Fertilizer and Agricultural Inputs Dealers' Association (AFADA), composed of more than 300 fertilizer dealers. In addition, an agricultural inputs dealers' network of 400 agribusinesses has been created. IFDC has assisted Albania in developing an efficient national agricultural statistical system. Fertilizer demand has remained constant during the past three years although prices have increased from 25% of world market to full commercial value. With IFDC assistance Albania has begun importing fertilizer to meet its fertilizer needs. Studies by IFDC have shown that fertilizer demand can increase up to 100,000 tonnes per year (valued at US $17 million). The country is undergoing dramatic changes, from a negative growth in 1991 to an increase in GDP of about 11% in 1994. The inflation rate has dropped from 225.9% in 1991 to 12% in 1994 and is expected to reach 10% by 1996. Agriculture is growing and supporting food security goals of the Government.

The IFDC-Albania privatization project has resulted in a network of more than 300 private dealers who now supply fertilizer and other agricultural inputs at market costs to more than one-half million private farmers who are adjusting to a market economy. Agricultural production is improving. After declines in 1990 and 1991, Albanian agricultural production increased by 18% in 1992 and by 14% in 1993. The latest estimates indicate an 8% increase in 1994. These increases are highly significant since agriculture accounts for more than one-half of Albania's Gross Domestic Product (GDP).

Privatization has moved rapidly in Albania following the 40 years of collectivization, which essentially eliminated private-sector agriculture and agri-input marketing. In 1989 the Albania Ministry of Economy reported essentially no private land ownership with 515,151 ha in crop production by collectives and 154,566 ha in production by state farms. All fertilizers were produced in state-owned factories and distributed through the state system. Today, land reform and redistribution are virtually complete, with about 95% of usable land having been transferred to private farms. The Government of Albania (GOA) still owns two fertilizer plants; however, fertilizer importation and distribution are in the hands of private entrepreneurs.

IFDC Recommendations and Accomplishments

IFDC has evaluated the technical, economic, and environmental feasibility of continued operation of the two GOA-owned fertilizer complexes. Recommendations have been made to privatize the nitrogen factory and to close the phosphate factory. Other recommendations have been made to the GOA to remove import-related taxes on fertilizers and to develop and implement an environmentally and economically sound fertilizer production and importation strategy.

Emergence of Dealer Organization

IFDC has provided assistance in creating and nurturing a 300-

member organization, AFADA. This dealer organization has provided major impetus to the privatization process. AFADA publishes an agribusiness newsletter, has sponsored a national conference on privatization of small- and medium-scale enterprises in the agro-industrial sector, has petitioned the GOA to remove restrictive import taxes, and in March 1994 arranged the first private sector import of fertilizers into post-reform Albania. IFDC has assisted AFADA entrepreneurs with a number of details associated with their first fertilizer imports, including facilitating a best offer from an international trading company, assisting in obtaining letters of credit, arranging trade financing, fixing vessels for transport of fertilizer, and helping to develop international business contacts among dealers. Fertilizer imports (primarily urea and ammonium nitrate) totaled about 40,000 tonnes in 1994 with product being primarily sourced from the Ukraine, Greece, and Bulgaria.

Banking and Credit

As the private sector marketing activity increased, so did the need for short-term credit. A substantial credit requirement was envisaged in order to sustain a viable fertilizer trade sector. To relax private sector financial constraints, IFDC, in conjunction with the Albanian banks and the two domestic fertilizer factories, developed detailed short-term bank credit and mercantile trade credit procedures based on the need and credit worthiness of fertilizer dealers. Mercantile credit was initiated by the two domestic fertilizer factories to stimulate off-season fertilizer movement and create increased financial capabilities among the dealers. A total of about 200 million leks (about US $2.0 million) in bank credit for fertilizer purchases was issued from December 1992 through September 1994.[1] During the same period, the Fier Nitrogen Fertilizer Factory (FNFF) and the Lac Superphosphate Factory (LSF) provided a total of 254 million leks (almost US $2.6 million) in mercantile credit.

Furthermore, the Savings Bank of Albania and the National Commercial Bank provided trade financing for the issue of letters of credit for the importation of 5,000 tonnes of urea and ammonium nitrate by one group of importers and several individual importers. The importers totally retired the debt before the fertilizer arrived at the Port of Durres beginning in late March 1994.

To assist with institutionalizing banking and mercantile credit for the private sector, IFDC conducted several in-country and overseas training programs during 1993 with the objective of upgrading the skills of senior credit agency managers and private sector dealers in credit management, business administration, and defining private sector investment priorities and opportunities in the free market system.

On January 13, 1994, the President of Albania issued Decree No. 752, which decreased the custom tax on fertilizers from 30% to 5% of the c.i.f. value. This action contributed substantially to successful fertilizer imports. A 15% turnover (sales) tax remains on fertilizer despite the efforts of IFDC and AFADA.

Albania will be able to achieve virtual self-sufficiency in nitrogen fertilizers if an ensured supply of natural gas is provided to the Fier nitrogen fertilizer production complex. Assuming removal of import duties, the availability of imports from the world market will ensure competition, which will provide the Albanian farmers with a reasonably priced supply of fertilizers.

SARA Project

At the request of the Government of Albania, USAID has implemented the Support for Agriculture Restructuring in Albania (SARA) Project to assist the public and private sectors to respond to the challenges inherent in transforming a centrally planned economy to one driven by free market forces.

One of the objectives of the SARA project involves agribusiness management training. Part of this training involves the use of training modules. IFDC developed the materials for Training Module No. 1, entitled Agribusiness Marketing and Commodity Systems. Other training modules may be prepared by IFDC during the course of the project. The training modules will be used to complement the work of the other members of the SARA consortium which, in addition to the project leader, Winrock International, includes Virginia Polytechnic Institute, Ronco International, and IFDC.

[1]Exchange rate was approximately 98 leks/U.S. dollar during the third quarter of 1993 when most of the credit was provided. Current exchange rate (September 1994) is approximately 85 leks/U.S. dollar.

IFDC's Impact in Asia
The Bangladeshi Example

One of IFDC's most outstanding success stories is in Bangladesh, where a 15-year project has completely restructured the fertilizer sector and instituted a freely competitive marketing system, which created a network of 170,000 private entrepreneurs. By eliminating fertilizer subsidies and other support costs, the Government of Bangladesh has saved more than US $100 million since 1988. A prime result of this project was Bangladesh's achievement of self-sufficiency in rice in the early 1990s. As a result of this project, all fertilizer importation is handled by the private sector.

The improvement of marketing and processing of fruit and vegetables is an important part of the Agrobased Industry and Technology Development Project. Here a load of popular jack fruit is delivered to market in Dhaka. The seeds are also used in traditional dishes.

IFDC's assistance to the Government of Bangladesh continued in 1994 through implementation of the USAID-funded Fertilizer Distribution Improvement (FDI)-II Project, which ended in August 1994, and the design of the Agrobased Industry and Technology Development Project (ATDP).

The goal of the FDI-II project was to increase agricultural production through the increased use of fertilizers. During 1994 a major emphasis was placed on sustaining the gains made in (1) fertilizer policy reform, (2) technology transfer and human resource development, (3) banking system development, and (4) upgrading of the management information system. Some of the key activities in each of these areas are discussed in the following sections.

Fertilizer Policy Reforms

The major emphasis was on maintaining a market environment that promoted increased fertilizer trade and encouraged private sector investment. This included a continuation of free market pricing, direct imports by the private sector, and private sector direct lifting of fertilizer from factories. A national association of more than 800 fertilizer distributors (the Bangladesh Fertilizer Association) was established to represent the private sector's interests in fertilizer sector development.

Technology Transfer and Human Resources

The FDI-II project continued to place great emphasis on human resource development to upgrade

the technical knowledge and business acumen of fertilizer-sector personnel including entrepreneurs, bankers, Department of Agricultural Extension staff, Government officials, and farmers. Technology transfer activities focused on upgrading technical knowledge of improved agricultural technology. During 1994, 115 farm-level demonstrations (48 in the private sector and 67 in the public sector) were conducted. In addition, 7 technical brochures and point-of-purchase displays were completed and distributed to the public and private sectors during the year.

National training programs for 467 fertilizer distributors and dealers, bankers, and government officials were completed under the FDI-II project in 1994. In addition, 22 persons participated in international study programs.

Banking System Development

The seed money (US $15 million) used to finance the commercial credit program in 1989 was instrumental in encouraging the financial institutions to provide working capital for private traders. During 1994 IFDC focused on improving the loan appraisal and loan management skills of the banks. This was accomplished through training programs, one-on-one technical assistance discussions with bank officials, and the provision of accurate and timely information on fertilizer market conditions.

Management Information System

During 1994 activities of the management information system (MIS) component focused on continuing to provide the public and private sector with timely reports on the impact of policy reform and fertilizer market conditions throughout the country. The MIS system was expanded to cover 61 of the 64 districts in the country, and the structure of the MIS component of the project was strengthened to improve efficiency in data collection, analysis, and reporting and to facilitate an orderly transition of the MIS function to ATDP.

IFDC's work under FDI-II included activities that focused on environmental and legislative issues related to the sustainability of the fertilizer marketing system in the private sector. A draft fertilizer control order was completed and submitted to the Ministry of Agriculture for review. Subsequently, a *Fertilizer Sampling Manual* and an *Analytical Manual for Fertilizer Materials* were developed and submitted to the Ministry of Agriculture to support implementation of the regulatory system.

The potential for environmental damage due to fertilizer production exists in the fertilizer industry. Recognizing the potential, the Bangladesh Chemical Industries Corporation and IFDC specialists completed a comprehensive assessment of the nitrogen production facilities in Bangladesh. The report entitled "An Environmental Assessment of the Ammonia and Urea Factories in Bangladesh" indicates that the factories are not adversely affecting the environment.

The FDI-II project was completed in 1994; highlighting the conclusion of the project was a seminar that focused on project achievements, lessons learned, and issues that continue to be a concern and potential threat to the sustainability of the open-market economy for fertilizers. The chief guest at the seminar was the Honorable Minister of Agriculture, Major General (Rtd) Majidul Huq. The guest of honor was the Honorable Ambassador of the United States, Mr. David M. Merrill. The project experience, including an overview of the project components, project achievements, and lessons learned under FDI-II, was included in a videotape on the project.

The FDI-II project has been a key technical assistance project in Bangladesh and has resulted in opportunities for further gains in agriculture/agribusiness development. Building upon the lessons learned and momentum gained under FDI-II, IFDC also completed the design of the USAID-funded ATDP in Bangladesh. The new project will include four main components: policy analysis and reform; technology transfer and training; commercial credit system development; and a management information system. The commodity subsectors to be included under the project are seeds, fertilizers, agri-machinery, poultry and livestock, and agri-processing.

Romania

With funding and support from USAID, IFDC imported into Romania about 17,000 tonnes of high protein animal feed supplement in 1992. Between June and October 1993, IFDC auctioned the feed supplement to private Romanian animal producers who paid near world market prices for the commodity.

The program, which the Romanian press labeled "the first real assistance to Romanian farmers by the United States of America," had two major purposes. The first was to introduce market economics and a free market experience to the Romanian farmers, and the second was to raise funds to be used to purchase equipment required for a national cadastre to return land to private ownership.

Those farmers who purchased and used the feed supplement made a private investment in animal production and were impressed with the performance of the feed and thus the return on their investment. Monitoring data showed excellent results with decreased mortality, decreased weaning period, increased lactation, improved weight gain, and decreased time to market (about 6 months compared with 11 months without the supplement). The program clearly created a demand for high quality animal feed supplement in Romania, which is estimated by IFDC to be 1 million tonnes/year.

The free market system has been introduced to Romania's agriculture sector. Roadside vegetable stands can be seen throughout the Romanian countryside.

IFDC's Impact in Central Europe
The Romanian Example

In Romania IFDC has introduced market economics to Romania's farmers and helped raise funds to purchase equipment needed for a national land survey designed to facilitate the return of land to private ownership. This project clearly created a demand for high-quality animal feed supplement in Romania, which is estimated to be 1 million tonnes per year. Because the feed supplement was sold through auctions, about US $6 million was raised for a cadastral survey. IFDC assisted with the formation of an association of private Romanian animal producers, now numbering about 100.

The auctions produced the equivalent of about US $6.0 million at the exchange rate prevailing during the first quarter of 1994. These funds will be used to purchase equipment and supplies for a cadastral survey. The work for this task has begun and is expected to continue through 1995. Secure land titles for private farmers are essential for the development of private animal production and agriculture in Romania.

IFDC also provided assistance for the formation of an association of private animal producers in Romania whose paid membership in 1994 was about 100. The organization is active in lobbying for the interests of private animal producers. During 1994 the members of the organization successfully completed several training workshops to strengthen their technical capacities.

The project succeeded in introducing free market concepts to Romanian farmers and generating funds for the cadastre. It is with this successful beginning that the work of IFDC in Romania is expected to continue with USAID support in 1995.

Tanzania

As a member of the FAO/World Bank Cooperative Programme mission, an IFDC economist visited Tanzania during 1994. This was a followup visit to an earlier World Bank mission in 1993 to identify a proposed Agricultural Factor Markets Project for Tanzania. As a result of these visits, a paper was prepared to clarify the issues involved in developing a liberalized fertilizer market in Tanzania. Also, recommendations for a successful transition to such a market were made.

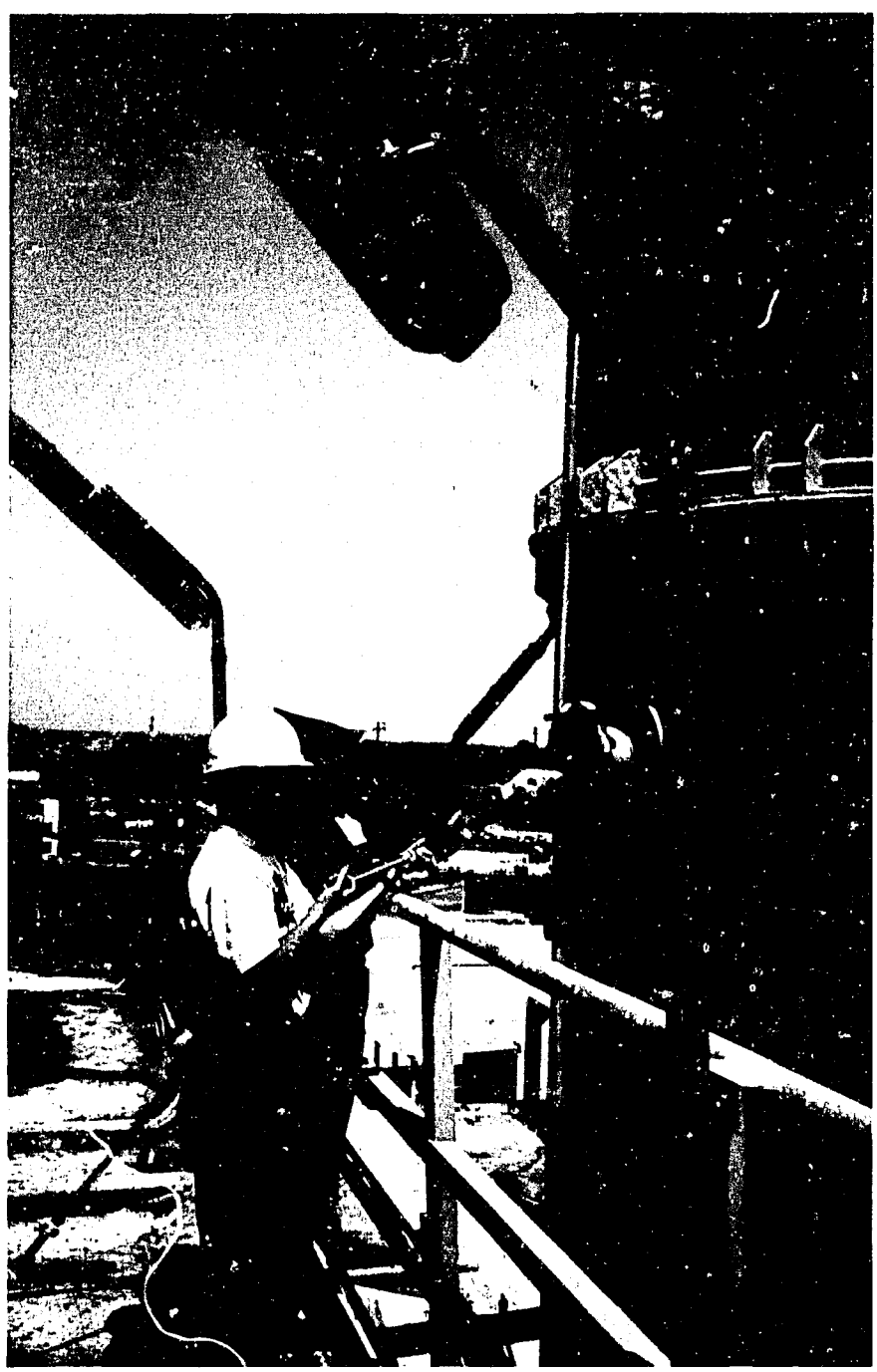
Fertilizer is a critical input for Tanzanian agriculture. Reform of this market to import technologically superior fertilizer products at the lowest possible costs is essential for long-term and sustained growth of Tanzania's agriculture. The conceptual framework of this paper has wider implications for the reform of other factor markets in Tanzania and elsewhere.

Venezuela

In September 1993 the Venezuelan Government removed all fertilizer subsidies and instructed Petroquimica de Venezuela S. A. (PEQUIVEN), the country's state-owned sole producer of fertilizer, to restructure its operations to make them competitive in a free and open market environment. By 1996 PEQUIVEN plans to privatize most, if not all, of its operations. To this end, PEQUIVEN obtained the services of IFDC to assist its staff in the design and implementation of this transition from a public, subsidized enterprise to one that is market driven and partially or totally private. In accordance with PEQUIVEN's request, IFDC has begun implementing the recommended reforms. The recommendations included the following elements:

- Determining the domestic market situation and methods for capturing and servicing a major market share.
- Examining the physical distribution system and developing a plan for improving the technical and economic efficiency of these operations.
- Identifying and prioritizing the constraints to the efficient marketing of fertilizer in Venezuela.
- Evaluating the domestic phosphate rock mining and beneficiation operations at the Riecito mine and formulating a plan for a more efficient integration of the mining operations into the Moron operations.

Mrs. Isabelita Barreiro, PEQUIVEN Process/ Projects Engineer, and Don Young, IFDC Senior Engineering Specialist, sample exit gases at PEQUIVEN's NPK plant.



IFDC's Impact in Latin America
The Venezuelan Example

Since September 1993 IFDC has been assisting Petroquímica de Venezuela S.A. (PEQUIVEN) in the design and implementation of its transition from a previously subsidized enterprise to one that is market-driven. This restructuring project is producing tangible results. For example, PEQUIVEN's overall fertilizer production capacity has increased from 60% to more than 88%. The production rates of the ammonia/urea and phosphoric acid units are nearing 100% capacity. Improved production efficiency in the phosphoric acid and NPK granulation plants produced a saving of about US $10,000 per day. IFDC introduced a preventive maintenance program that has decreased unscheduled downtime by about 50%. The control of credit to dealers, dealers' inventory, and past due collections has improved PEQUIVEN's cash flow. The marketing train-the-trainer program implemented by IFDC has quickly expanded PEQUIVEN's capability to develop an entirely new customer-oriented sales force. The PEQUIVEN project is a classic example of the integrated application of IFDC's broad spectrum of practical market-oriented technical, financial, marketing, and management skills to meet a client's complex needs.

Primary crushing station at PEQUIVEN's Riecito phosphate rock mine.

- Evaluating the phosphoric acid production unit at Moron with emphasis on improving the technical and economic efficiency of the unit.
- Evaluating the compound NP/NPK granulation unit to determine needed modifications for improving the efficiency of the unit.
- Analyzing PEQUIVEN's management and business operations.

IFDC has begun a program to train a cadre of fertilizer and agri-inputs dealers and salespersons and in 1994 provided four resident counterpart managers to work at the Moron complex in concert with Moron management. These managers are covering the areas of marketing and management, phosphoric acid production, NPK fertilizer production, and ammonia/urea production. The PEQUIVEN project is a classic example of the integrated application of IFDC's broad spectrum of practical commercially oriented technical, marketing, financial, and management skills to solving a client's complex needs. The techniques used by IFDC in assisting PEQUIVEN to move from the public sector into the market-driven private sector are applicable to several other IFDC initiatives currently being developed or underway in Eastern Europe, the former Soviet Union, and elsewhere.

Sustainable Agricultural Growth Through Capacity Building

In assisting developing countries to achieve food security, we must first help them analyze their problems, determine the necessary course of action, and mobilize the resources needed to complete the necessary tasks. In other words, we must empower them with the capacity to solve their own problems. During 1994 IFDC's training component continued to play a vital role in developing countries by strengthening national capacities of 55 countries by providing training opportunities for a total of 468 individuals.

IFDC's Human Resource Development Unit develops and manages group and individual training for private agribusiness people, government policymakers, agriculturalists, and research scientists from developing countries worldwide. Most training programs at IFDC are developed and implemented in collaboration with universities, private voluntary organizations, and Federal agencies. This gives training participants access to a broad range of expertise. During 1994, 468 persons participated in IFDC group and individual training programs. Nine percent of the trainees were women.

IFDC participated in IFA's Regional Conference for Africa, which was held in Dakar, Senegal, in 1994. Pictured from left are a representative of the Senegalese Fertilizer Company, ICS; Dr. Uzo Mokwunye, Director, IFDC Africa Division; and IFA's General Secretary, Luc Maene.

Global training programs

In cosponsorship with the Fertiliser Association of India (FAI) and Asosiasi Produsen Pupuk Indonesia (APPI), IFDC's distribution and marketing specialists organized the 3-week International Study Tour on Fertilizer Distribution and Handling. The program was attended by 28 senior- and middle-level officials and managers from 12 countries who are involved in the physical distribution of fertilizers. The study tour was held in India, Indonesia, and Singapore.

IFDC's agronomy and marketing specialists organized a 2-week International Study Tour on Advances in Fertilizer and Irrigation Technology in the United States at various locations in the United States. The study tour was attended by 17 participants from 12 countries.

IFDC's marketing specialists organized a 4-week Training Program on Fertilizer Marketing Challenges at various locations in the United States. Twenty-three participants from 12 countries attended the program. The program addressed challenges in fertilizer marketing due to privatization of the fertilizer sector.

In cooperation with the University of Florida, the International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT), and the International Consortium for Agricultural Systems Applications (ICASA), IFDC's crop modelers organized the 2-week Training Program on Computer Simulation of Crop Growth and Management Responses in Gainesville, Florida. The program was attended by 34 participants (including five women) from 17 countries.

In cosponsorship with APPI, IFDC's marketing specialists and

economists organized a 2-week training program, Fertilizer Marketing Training Program: New Challenges, in Jakarta, Indonesia. The program was attended by 33 participants (including three women) from 11 countries.

IFDC staff in Africa organized the 2-week Training Program on Efficient Marketing of Fertilizers in sub-Saharan Africa in Lomé, Togo. The program, presented in English and French, was attended by 16 participants from 14 countries. A 2-day field trip was organized to visit a fertilizer granulation and blending plant and a bagging company in Abidjan, Côte d'Ivoire.

At the request of the Burkina Faso National Soil Research Institute, IFDC-Africa organized a 2-day training workshop for five Burkinabe soil scientists at Lomé, Togo. The workshop entitled "Integrated Soil Fertility Management in West Africa" provided a forum for scientists in the Watershed Management Program to share with their Burkina Faso counterparts ideas and experiences on crop rotation, management of crop residue and manure, nutrient management under an agro-forestry system, and farmer-participatory approaches to integrated soil fertility management. The participants visited IFDC-Africa's research station at Davié, Togo, to observe on-going field research activities.

IFDC-Africa participated in the IFA Regional Conference for Africa in Dakar, Senegal, during 1994 to inform the fertilizer industry about challenges and opportunities in West Africa. Presentations were given on fueling sustainable growth in West African agriculture through capacity building, perspectives on bulk blending and blended fertilizers in West Africa, the need for effective fertilizer market development in Nigeria, the changing role of the State in the fertilizer sector in francophone West Africa: a case study of Benin, and an overview of fertilizer transactions in sub-Saharan Africa in 1993.

During 1994 IFDC-Africa organized a seminar on the use of local mineral resources for sustainable agriculture in West Africa. The seminar was a joint effort of the two networks at IFDC-Africa – the African Fertilizer Trade and Marketing Information Network (AFTMIN) and the West African Fertilizer Management and Evaluation Network (WAFMEN). Ninety-two participants, representing 14 countries in sub-Saharan Africa, two countries in Europe (France and Netherlands), and United States, discussed the use of local mineral resources to reverse soil fertility decline and increase farm production and income. The seminar was funded by the Netherlands Development Cooperation (DGIS), and the WAFMEN participants were sponsored by the Agence de Coopération Culturelle et Technique (ACCT).

Specialized training programs

During 1994, some 314 participants, including 44 women, participated in 23 specialized training programs covering such areas as agribusiness planning, crop modeling, environmental assessment, fertilizer production, international procurement and import financing, and marketing.

Country-specific study tours

Study Tour for Polish Fertilizer Industry Commercial Managers and Dealers

Because the Polish economy is being transformed into a market-oriented system, the country's businesses and industries are eager to learn how to make their enterprises more efficient and competitive. Polish managers are looking for ways to develop previously unfamiliar entrepreneurial skills in order to adapt to market-driven systems. In this new environment they have been suddenly thrust into making the hard decisions regarding production goals and costs, pricing, product selection, distribution, and marketing.

To assist the Polish fertilizer industry in making this transition, IFDC organized a specialized study tour of the United States for ten of Poland's leading fertilizer industry managers. The objectives of the tour were to provide these managers with an in-depth look at U.S. fertilizer granulation techniques and commercial factories operating in a free market economy. An equally important objective was to observe a market-oriented dealer network that serves as a private extension service.

After a series of lectures and discussions on distribution and marketing at IFDC, the Polish managers were conducted by IFDC officials on a tour of a number of fertilizer production plants, fertilizer dealers, and farm service centers.

Environmental Regulations Study Tour for Bangladesh Fertilizer Officials

A 7-member team of Bangladesh fertilizer plant officials gained a better understanding of environmental issues and regulations in the United States as they affect the fertilizer industry. During the study tour the officials assessed the environmental and safety programs of U.S. fertilizer factories. With their U.S. hosts, the team members discussed fertilizer production processes; quality control, marketing, and distribution techniques for solid and liquid fertilizers; and environmental issues related to production plants.

Study Tour for Officials of Albania's Agricultural Statistical Directorate

During 1994 IFDC conducted a 2-week study tour in the United States for four officials of the Directorate of Information and Statistics, MOAF, to apprise Albanian Government officers of the technologies and developments of countries operating in free and competitive marketing systems.

On field visits to various state and Federal agricultural statistical service offices, the group learned about basic and advanced technologies in agricultural statistical services principally in the areas of data collection and survey techniques, census, and management information systems. The visits were complemented with lengthy discussions with government officers in charge of the bureaus visited. The discussions were centered around the application of the technologies in Albania, the resources needed, and the limitations.

Agricultural Inputs Business Planning and Finance Study Tour for Albanian Ag-Input Dealers and Bankers

IFDC organized and conducted a study tour on agricultural inputs business planning and finance for a group of 19 bankers and ag-input dealers during 1994. During the segment of the program that was conducted at IFDC Headquarters, the participants and their leaders discussed a range of topics such as commercial credit, banking services for agribusiness, and marketing crop protection chemicals. In addition, the participants observed various components of agribusiness during field visits to a seed testing laboratory, a commercial bank, a swine farm, seed stores, farmers' cooperatives, family-owned farms, fertilizer plants, fertilizer equipment manufacturers, trade associations, and governmental agencies.

Study Tour on Agribusiness Planning, Development, and Commercial Finance

IFDC conducted a 2-week study tour for two Bangladesh officials – the Additional Secretary, Ministry of Agriculture, and the Additional Secretary, Ministry of Finance (Banking) – during 1994. The purpose of the tour was to introduce concepts of operating and managing agribusiness enterprises and private-sector companies and the role of private banks in support of these operations. The tour included visits to and discussions with several companies and institutions in the United States related to agribusiness, fertilizer production, and banking and credit organizations. Some of the activities that were included on the agenda were (1) an introduction to the role of extension in U.S. agriculture; (2) discussions with credit organizations that finance agribusiness operations; (3) an overview of the production of fertilizers and soil testing for recommendations; (4) the observation of phosphate mining and land reclamation methods; (5) discussions with international fertilizer trading companies; and (6) an overview of the services provided by the banking community.

REPORT OF INDEPENDENT ACCOUNTANTS

To the Board of Directors
International Fertilizer Development Center

We have audited the accompanying balance sheet of International Fertilizer Development Center (IFDC) as of December 31, 1994, and the related statements of revenue, expenses and changes in fund balance, functional expenses, and cash flows for the year then ended. These financial statements are the responsibility of IFDC's management. Our responsibility is to express an opinion on these financial statements based on our audit. The financial statements of IFDC for the year ended December 31, 1993, were audited by other auditors, whose report, dated March 11, 1994, expressed an unqualified opinion on those statements.

We conducted our audit in accordance with generally accepted auditing standards. Those standards 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. An audit also includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall financial statement presentation. We believe that our audit provides a reasonable basis for our opinion.

In our opinion, the financial statements referred to above present fairly, in all material respects, the financial position of International Fertilizer Development Center as of December 31, 1994, and the results of its operations and its cash flows for the year then ended, in conformity with generally accepted accounting principles.

Coopers & Lybrand L.L.P.

Birmingham, Alabama
March 17, 1995

International Fertilizer Development Center
Balance Sheets - Assets

December 31, 1994 And 1993

	1994	1993
CURRENT FUND		
Cash and cash equivalents	$ 3,133,361	$ 2,896,460
Short-term investments	100,000	0
Amounts receivable from donors (Note 4)	1,330,166	6,427,078
Other accounts receivable	990,449	1,388,432
Advances to employees	65,042	86,192
Supplies inventory	129,474	144,408
Prepaid expenses	69,405	67,001
	$ 5,817,897	$ 11,009,571
BUILDINGS AND EQUIPMENT FUND		
Buildings	$ 5,976,400	$ 5,976,400
Equipment	5,041,758	5,150,179
	11,018,158	11,126,579
Less: accumulated depreciation	(7,775,475)	(7,515,344)
	$ 3,242,683	$ 3,611,235

See notes to financial statements.

International Fertilizer Development Center
Balance Sheets - Liabilities And Fund Balances

December 31, 1994 And 1993

	1994	1993
CURRENT FUND		
Accounts payable	$ 330,909	$ 431,951
Accrued annual and sick leave (Note 2)	1,730,501	1,797,146
Deferred revenue (Note 4)	2,614,591	7,624,887
Total liabilities	4,676,001	9,853,984
Fund balance	1,141,896	1,155,587
	$ 5,817,897	$ 11,009,571
BUILDINGS AND EQUIPMENT FUND		
Contract retainage	$ 0	$ 421
Fund balance	3,242,683	3,610,814
	$ 3,242,683	$ 3,611,235

See notes to financial statements.

International Fertilizer Development Center
Statements Of Revenues, Expenses, And Changes In Fund Balances
for the years ended December 31, 1994 And 1993

	Current Fund		Buildings and Equipment Fund		Total All Funds	
	1994	1993	1994	1993	1994	1993
Revenue:						
Grants	$ 6,885,542	$ 18,488,621	$ 0	$ 0	$ 6,885,542	$ 18,488,621
Recoverable project costs	4,799,868	4,687,985	0	0	4,799,868	4,687,985
Other	8,688	260,653	0	0	8,688	260,653
Total revenue	11,694,098	23,437,259	0	0	11,694,098	23,437,259
Expenses:						
Field programs	3,151,213	4,710,206	38,059	58,625	3,189,272	4,768,831
Research	2,172,011	2,491,726	121,828	117,834	2,293,839	2,609,560
Outreach	4,104,594	13,263,463	128,723	132,016	4,233,317	13,395,479
General and administrative	2,343,341	2,713,355	79,100	75,228	2,422,441	2,788,583
Total expenses	11,771,159	23,178,750	367,710	383,703	12,138,869	23,562,453
Excess (deficiency) of revenue over expenses	(77,061)	258,509	(367,710)	(383,703)	$ (444,771)	$ (125,194)
Other changes in fund balances:						
Fund balances, beginning of period	1,155,587	1,116,110	3,610,814	3,807,332		
Transfers to (from) current fund for equipment acquisitions, capital lease payments, and retainage	421	(187,185)	(421)	187,185		
Foreign currency translation adjustment	62,949	(31,847)				
Fund balances, end of period	$ 1,141,896	$ 1,155,587	$ 3,242,683	$ 3,610,814		

See notes to financial statements.

International Fertilizer Development Center
Statements Of Functional Expenses

for the years ended December 31, 1994 And 1993

	Field Programs		Research		Outreach		Administrative		Total Expenses	
	1994	1993	1994	1993	1994	1993	1994	1993	1994	1993
Personnel compensation	$ 1,797,141	$ 2,145,456	$ 1,145,018	$ 1,220,393	$ 2,041,097	$ 1,803,911	$ 1,290,126	$ 1,366,079	$ 6,273,382	$ 6,535,839
Personnel benefits	327,528	497,790	398,170	415,980	533,776	507,407	371,503	386,457	1,630,977	1,807,634
Travel and transportation	486,121	842,749	157,231	192,992	764,824	3,568,859	130,527	210,260	1,538,703	4,814,860
Occupancy	27,336	41,144	155,456	202,836	158,390	208,780	155,456	202,837	496,638	655,597
Telephone and telegraph	47,292	179,837	33,646	43,704	74,119	87,891	34,937	40,274	189,994	351,706
Rental of equipment	74,724	177,731	38,915	46,236	78,484	134,634	5,289	20,120	197,412	378,721
Contractual research and development	8,962	104,270	41,261	91,961	0	12,100	196,265	0	246,488	208,331
Other contractual services	125,425	313,896	74,683	70,244	152,998	653,142	0	293,788	353,106	1,331,070
Materials and supplies	202,951	351,128	96,153	174,976	244,610	6,206,341	123,699	160,701	667,413	6,893,146
Postage	18,919	26,589	13,149	13,022	13,581	26,907	13,709	12,874	59,358	79,392
Insurance	34,814	29,616	18,329	19,332	42,715	53,491	21,830	19,965	117,688	122,404
Miscellaneous	0	0	0	50	0	0	0	0	0	50
Total expenses before depreciation	3,151,213	4,710,206	2,172,011	2,491,726	4,104,594	13,263,463	2,343,341	2,713,355	11,771,159	23,178,750
Depreciation of buildings and equipment	38,059	57,593	118,682	114,831	122,827	128,881	69,831	69,865	349,399	371,170
Loss on disposal of equipment	0	1,032	3,146	3,003	5,896	3,135	9,269	5,363	18,311	12,533
	38,059	58,625	121,828	117,834	128,723	132,016	79,100	75,228	367,710	383,703
Total expenses	$ 3,189,272	$ 4,768,831	$ 2,293,839	$ 2,609,560	$ 4,233,317	$ 13,395,479	$ 2,422,441	$ 2,788,583	$ 12,138,869	$ 23,562,453

See notes to financial statements.

International Fertilizer Development Center
Statements Of Cash Flows

for the years ended December 31, 1994 And 1993

	1994	1993
Cash flows from operating activities:		
Deficiency of revenue over expenses	$ (444,771)	(125,194)
Adjustments to reconcile deficiency of revenue over expenses to net cash provided by operating activities:		
Depreciation	349,399	371,170
Loss on disposal of equipment	18,311	12,533
Other, net	(2,258)	0
Changes in assets and liabilities:		
(Increase) decrease in short-term investments	(100,000)	98,000
Decrease in amounts receivable from donors	5,096,912	2,084,498
Decrease in advances to employees	21,150	55,491
Decrease in other accounts receivable	397,983	842,513
Increase in prepaid expenses	(2,404)	(37,402)
Decrease (increase) in supplies inventory	14,934	(38,413)
Decrease in accounts payable and accrued annual and sick leave	(167,687)	(518,872)
Decrease in deferred revenue	(5,010,296)	(1,834,735)
Net cash provided by operating activities	171,273	909,589
Cash flows from investing activities:		
Proceeds from sales of equipment	2,679	0
Capital expenditures	0	(187,185)
Net cash provided by (used in) investing activities	2,679	(187,185)
Effect of foreign currency exchange rate changes on cash	62,949	(31,847)
Net increase in cash and cash equivalents	236,901	690,557
Cash and cash equivalents, beginning of year	2,896,460	2,205,903
Cash and cash equivalents, end of year	$ 3,133,361	$ 2,896,460

See notes to financial statements.

International Fertilizer Development Center
Notes to Financial Statements

1. General

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.

2. Summary of Significant Accounting Policies

The financial statements of IFDC have been prepared on the accrual basis of accounting. The accounts of IFDC are maintained in accordance with the principles of fund accounting to ensure the observance of limitations and restrictions placed on the use of resources available to IFDC. The following is a summary of significant accounting policies followed by IFDC:

Grants - Grants are recorded as receivable in full at the date of the grant award with the 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.

Cash and Cash Equivalents - IFDC considers all highly liquid investments purchased with an original maturity of three months or less to be cash equivalents.

Short-Term Investments - Short-term investments, which consist of bank certificates of deposit, are recorded at cost, which approximates market value.

Supplies Inventory - Inventories of supplies are valued at the lower of cost or replacement cost. The first-in, first-out method is used to determine the inventory cost.

Buildings and Equipment - Buildings and equipment are recorded at cost. Major renewals and betterments are capitalized; maintenance and repairs are charged to operations as incurred. Depreciation is provided on the straight-line method over the estimated useful lives of the assets ranging from three to thirty-five years. When items of buildings or equipment are sold or retired, the related cost and accumulated depreciation are removed from the accounts and any gain or loss is included in the results of operation.

Notes to Financial Statements, Continued

Accrued Annual and Sick Leave - Annual and sick leave accrue at the monthly rate of 16 hours and 8 hours, respectively. Employees may carry forward annual leave up to a maximum of 384 hours. Annual leave in excess of 384 hours can be converted to sick leave, until accrued sick leave reaches 1,200 hours. Thereafter, only earned sick leave will be accrued. Upon termination, employees are paid for accrued annual leave up to 384 hours. All unused sick leave is forfeited upon termination.

Income Tax Status - IFDC has a tax determination letter from the Internal Revenue Service stating that it qualifies under the provisions of Section 501c(3) of the Internal Revenue Code and is exempt from federal income taxes.

Foreign Currency - IFDC records transactions denominated in foreign currency on a monthly basis, using the average monthly exchange rate. Bank accounts denominated in foreign currency are translated as of the ending balance sheet date using the current exchange rate.

Reclassifications - Certain reclassifications have been made to the 1993 financial statements to conform with the 1994 presentation. These reclassifications had no impact on fund balance or the deficiency of revenue over expenses.

Functional Expenses - 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 following programs and supporting services that benefit from such costs:

a. **Field Programs** - The departments are located primarily in Africa and Asia and specialize in problems indigenous to these regions.

b. **Research** - The department is responsible for 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.

c. **Outreach** - The department is responsible for assisting in the transfer of technology to less developed countries through information development, collection, analysis and reporting and human resource development.

d. **Administrative** - The department is 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.

Notes to Financial Statements, Continued

3. Operating Leases

IFDC leases certain of its office equipment under agreements classified as operating leases. The lease terms expire in 1996. Future minimum lease payments under operating leases having noncancelable terms of more than one year are as follows:

1995	$ 36,591
1996	12,197
	$ 48,788

Rent expense under these leases was approximately $37,000 for the years ended December 31, 1994 and 1993.

4. Grants

Grants for the years ended December 31, 1994 and 1993 are summarized as follows:

	1994		1993	
	Restricted	Unrestricted	Restricted	Unrestricted
Grants received:				
United States Agency for International Development (AID)		$ 1,976,000	$ 15,365,921	$ 2,500,000
Federal Ministry of Agriculture Nigeria	$ 166,892			
World Bank		600,000		860,000
Centre de Cooperation Internationale en Recherche Agronomique pour le Development (CIRAD)			83,552	
	166,892	2,576,000	15,449,473	3,360,000
Amounts deferred during the prior year	5,875,054	1,684,428	7,297,347	1,880,000
	6,041,946	4,260,428	22,746,820	5,240,000
Less: amounts deferred to future periods	(1,258,988)	(1,242,450)	(5,875,054)	(1,684,428)
Other adjustments	(915,394)		(1,938,717)	
Revenue recognized in current period	$ 3,867,564	3,017,978	$ 14,933,049	3,555,572
		3,867,564		14,933,049
Total restricted and unrestricted		$ 6,885,542		$ 18,488,621

Other adjustments in 1994 consist primarily of the write-off of a previously recorded deferred revenue amount related to AID procurement grants for which total funding was not required for project completion. Other adjustments in 1993 consist primarily of the write-off of a previously recorded deferred revenue amount related to a World Bank grant for which funding was canceled during 1993.

In addition to grant amounts deferred to future years, as indicated above, deferred revenue at December 31, 1994 and 1993 includes $113,153 and $65,405, respectively, of cash collected on reimbursable cost projects for which revenue has not been recognized.

During 1993, IFDC received restricted grants from AID of approximately $15,366,000. Approximately $15,352,000 of such grants related to feed procurement and technical assistance in Eastern Europe.

During 1994 and 1993, IFDC received unrestricted funding from AID in the amount of $1,976,000 and $2,500,000, respectively, which represents approximately 75% of IFDC's unrestricted funding.

Amounts receivable from donors at December 31, 1994 and 1993 are summarized as follows:

	1994		1993	
	Restricted	Unrestricted	Restricted	Unrestricted
AID	$ 498,357	$ 656,000	$ 4,503,906	$ 842,428
International Development Research Centre			104,484	
Directoraat Generalaal Voor Internationale Samenwerking (Netherlands)	175,809		976,260	
	$ 674,166	656,000	$ 5,584,650	842,428
		674,166		5,584,650
Total restricted and unrestricted		$ 1,330,166		$ 6,427,078

5. Implementation of SFAS 116 and 117

Effective for financial statements issued for fiscal years beginning after December 15, 1994, IFDC will be required to implement Statement of Financial Accounting Standards (SFAS) No. 116, "Accounting for Contributions Received and Contributions Made," and SFAS No. 117, "Financial Statements of Not-for-Profit Organizations." The most significant provision of SFAS No. 116 is the recognition of pledges in the financial statements. SFAS No. 117 requires a change in the display of financial statements from those based on fund accounting to a display based on the concept of "net assets." The impact of these pronouncements has not been determined. IFDC plans to adopt these standards for the year ended December 31, 1995.

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(as of December 31, 1994)

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(as of December 31, 1994)

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1. Left during 1994.
2. Extended leave.

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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(as of August 1995)

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Acronyms and Abbreviations

ACCT	Agence de Cooperation Culturelle et Technique
AFADA	Albanian Fertilizer and Agricultural Inputs Dealers Association
AFTMIN	African Fertilizer Trade and Marketing Information Network
AIDAB	Australian International Development Assistance Bureau
APPI	Asosiasi Produsen Pupuk Indonesia
AS	Ammonium Sulfate
ATDP	Agrobased Industry and Technology Development Project
AVRDC	Asian Vegetable Research and Development Center
BNF	Biological Nitrogen Fixation
CENA	Center for Nuclear Energy in Agriculture
CIAT	Centro Internacional de Agricultura Tropical
CIMMYT	International Maize and Wheat Improvement Center
CMDT	Compagnie Malienne pour le Developpement des Textiles
CORPOICA	Corporación Centro de Investigaciones Agropecuarias
DAP	Diammonium Phosphate
DGIS	Directoraat Generaal voor Internationale Samenwerking
EPA	Environmental Protection Agency
EROS	Earth Resources Observation Systems
FAI	Fertiliser Association of India
FAO	Food and Agriculture Organization of the United Nations
FASCOM	Farmers Services Companies
FDI	Fertilizer Distribution Improvement
FEWS	Famine Early Warning System
FNFF	Fier Nitrogen Fertilizer Factory
GDP	Gross Domestic Product
GIS	Geographic Information System
GOA	Government of Albania
IARCs	International Agricultural Research Centers
IBSNAT	International Benchmark Sites Network for Agrotechnology Transfer
ICASA	International Consortium for Agricultural Systems Applications
ICRAF	International Centre for Research in Agroforestry
IER	Institut d'Economie Rural
IFA	International Fertilizer Industry Association
IFDC	International Fertilizer Development Center
INIA	Instituto Nacional de Investigación Agropecuaria
IRRI	International Rice Research Institute
LSF	Lac Superphosphate Factory
MAP	Monoammonium Phosphate
MIS	Management Information System
MOAF	Ministry of Agriculture and Food
NOAA	National Oceanic and Atmospheric Administration
ORSTOM	Office de la Recherche Scientifique et Technique de Outre-Mer
PAPR	Partially Acidulated Phosphate Rock
PEQUIVEN	Petroquimica de Venezuela
SARA	Support for Agricultural Restructuring in Albania
SFMU	Soil Fertility Management Unit
SOFITEX	Société Burkinabe de Fibres et Textiles
SSP	Single Superphosphate
TFI	The Fertilizer Institute
TPR	Tilemsi Phosphate Rock
TSP	Triple Superphosphate
TVA	Tennessee Valley Authority
USAID	U.S. Agency for International Development
USDA	United States Department of Agriculture
WAFMEN	West African Fertilizer Management and Evaluation Network

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