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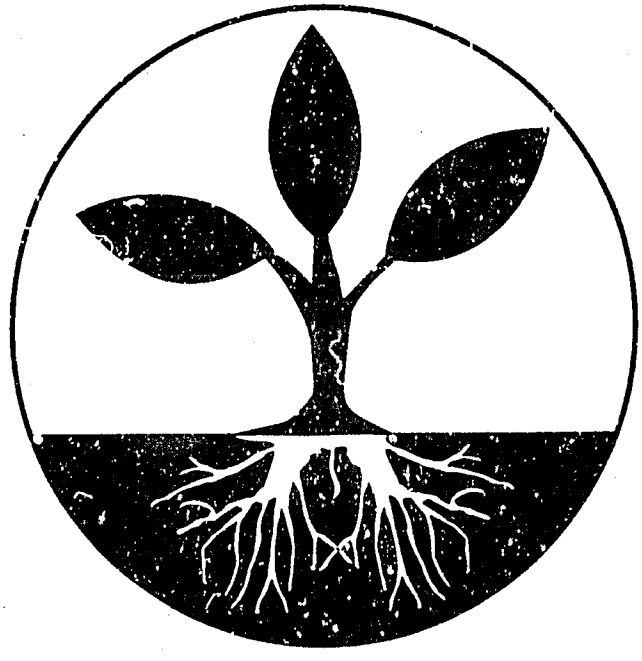
Abstracts

Lectures Presented at IFDC Training Program:

Plant Nutrient Management For Sustainable Agriculture

Muscle Shoals, Alabama U.S.A.
September 14-25, 1992



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Preface

"Sustainable agriculture" has been a vague concept to many agricultural workers who have been educated in specialized disciplines that use single-factor approaches to study small parts of crop production. For some, the concept was initially confused with "organic" and "low-input" agriculture. The concept of sustainability has evolved to mean the best utilization of available on-farm and off-farm resources, particularly management, based on an understanding of the highly interactive nature of various farming practices. This approach recognizes that practices are only more or less sustainable relative to each other, and the issues are very site, time, and circumstance specific. A central issue of sustainability is that systems must be economically viable but still preserve the natural resources, the environment, and the production capabilities for future generations. Sustainability has become, and will undoubtedly continue to be, the most unifying and basic concept guiding agriculture.

In the training program held at IFDC Headquarters in September 1992, invited experts and IFDC staff were asked to present lectures on the most salient issues pertaining to their subject areas regarding sustainability of crop production systems. The staff of IFDC and especially the invited speakers are commended for their excellent presentations. Although the program focused on plant nutrient management, it also emphasized that the concept of sustainability requires integrating various disciplines to develop the most logical approaches to best utilize available inputs and natural resources in specific production systems.

"Modern," high-external-input agricultural systems do not provide the answers on how to reverse declining productivity and the rapidly degrading natural resource base of agricultural systems. Hopefully, an understanding of how to apply the principles of sustainability will enable the participants to assist the farmers of their nations in adopting better farming practices. These better approaches are vital to man's survival.

This program was the second in IFDC's continuing effort to conduct training in the important area of sustainable agriculture. This publication contains the abstracts of key lectures that were presented in the 2-week program. Requests for more information on the program can be sent to IFDC.

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Program Manager

Application of Sustainability Concepts in Developed Agricultural Systems

Sustainability uses a systems approach at the farm level and considers that the goal of farmers should be to farm in accord with natural processes as much as is feasible. A farm is a biological entity that includes the farming family, soils, plants, animals, and other organisms.

Management practices based on sustainability revolve around good soil organic matter management, preventative pest management, biological diversity, and, in general, helping nature help the farmer.

Farmers must adopt practices that mimic natural systems to make their farms more sustainable. Natural systems recycle and retain nutrients, maintain soil cover, and are biologically diverse. The plants are obviously adapted to their environment. Conversely, traditional agricultural practices of monocultures, clean tillage, concentration of livestock, and reliance on chemical fertilizers and pesticides attempt to dominate and change nature. Such practices have reduced the capacity of landscapes to produce agricultural output throughout history, and the basic concept of dominating rather than working with nature must be corrected to ensure man's long-term survival and quality of life.

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Integration of Sustainability Concepts for Tropical Agricultural Systems

Other speakers will provide specific information on a variety of topics in the areas of chemistry, fertility, and conservation of tropical soils. I will attempt to integrate some of those topics and some experiences in tropical and temperate cropping systems research into an interdisciplinary and multicommodity perspective.

After several years in a quiescent state, topics like systems diversity and residue management are attracting renewed interest as we look to holistic natural resource management for help in developing more sustainable crop and animal production systems in all parts of the world. Tropical systems are characterized by unique features of weather, management (labor), polycropping, residue management, and rate of change for soil inorganic and organic components. In fact, most tropical systems have unique potential for sustainable agriculture. There are also challenges, however, because some of the features that offer promise also represent threats. The role of human social development in most tropical agriculture systems has been different from that in temperate systems. The crop, soil, and animal husbandry practices of tropical farmers may in general be characterized as more "natural" or more consistent with land-based life support systems. As we see today, those systems are not necessarily more productively stable, but they do represent a forum where the philosophical bases of soil conservation are not philanthropic or environmentally driven causes as much as they are a part of local diet, clothing, and hygiene, i.e., another part of life.

The key internal components of sustainable tropical farming systems are water management, crop residue and animal manure management, energy and nutrient cycling, and system diversity. External factors such as family labor availability, governmental policy, and public perception are also powerful forces on marketing produce and the use of external inputs. International research and development programs can enhance the contribution of internal and external components to sustainable farming systems, particularly where they strengthen bioregional self-sufficiency and support local value-added industry, rather than pursuing policies that amass agriculture-derived capital at great cost to nonrenewable or slowly renewing natural resources like soil and water.

Traditional technical and academic prejudices favoring disciplinary- and commodity-oriented research are of limited value, compared with interdisciplinary teams studying the multiple and complex interrelationships of crop rotations, tillage practices, and pest management alternatives. Ongoing research in the University of California-Davis Farming Systems Project emphasizes the identification of key principles and processes in a long-term crop rotation study. Many of the group research experiences are transferable to other systems and environments.

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Soil Resources of the Tropics and Subtropics

Soils in the tropics and subtropics are so diverse in their properties that few general statements can be presented. Of major importance is the limited influence that temperature has on soil management practices compared with its influence in colder temperate areas. Generally the soils of tropical and subtropical areas have low silt contents and thus low available water-holding capacity, and they lack a substantial supply of weatherable minerals that are rich in plant nutrients. Many soils in tropical and subtropical areas have exchangeable aluminum/base ratios that restrict root elongation into the subsoil and thus further restrict ion and water uptake by crop plants. These are not insurmountable problems, but management technologies to compensate for these limitations are required to sustain even low yields in many cases.

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Maintaining Chemical and Physical Properties of Tropical Soils

Soils in the tropics obey the same chemical and physical laws as soils in temperate areas. However, most soils in the tropics have a much lower total plant nutrient supply than do soils in temperate areas because they contain fewer weatherable minerals. Also, many soils in the tropics have lower cation exchange capacities, which means that the management of soil chemistry has to be more precise to avoid overliming or other cation imbalances. This also means that a much higher proportion of the plant nutrients in the natural soils are in organic forms. However, organic material grown on nutrient-poor soils may also be nutrient poor and, of course, any use of food or fiber entails the export of nutrients that can only be resupplied from fertilizer or nutrient-rich weatherable minerals. Desirable physical conditions in the surface soil are best maintained when actively growing vegetation is maintained. This is difficult in many tropical areas, especially when there are long dry seasons. Also, planting of crops at the beginning of a rainy season presents problems of high surface temperatures and potential seedling loss because there is no stored water in the soil at this time.

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Controlling Soil Erosion to Help Maintain the Resource Base

Controlling soil erosion is vital to conserving agricultural resources and maintaining the quality of the environment, which is by definition a primary component of sustainable agriculture. The importance of controlling soil erosion for maintaining soil productivity has been shown by field research. The ability to tolerate soil erosion while maintaining a high level of productivity varies greatly among soils and with other inputs and tillage capabilities. Soils that have deep, permeable surface horizons with no root-restricting subsoil layers will obviously tolerate more soil erosion losses than will shallow, less permeable soils.

Technology for predicting soil erosion, such as the Universal Soil Loss Equation (USLE), has been used for many years to assist on-farm conservation planning. These methodologies are constantly being improved, and the empirically based systems are being replaced by computer-assisted process-based models. Conservation-tillage (no-till, strip-till, ridge-till, mulch-till, and other reduced-tillage systems) is presently the most important and versatile tool to minimize soil erosion from cultivated land. Conservation tillage is essential to maintaining high yields and improving the quality of runoff water, but it requires specific management practices and, in some cases, specialized equipment to accomplish erosion control.

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Soil Organic Matter—Its Importance and Maintenance

Carbon input, soil texture, tillage, water, and temperature all affect the equilibrium organic matter content of soils. This is illustrated by the data from long-term experiments at Rothamsted and Woburn in the United Kingdom. Some of these experiments have continued with unchanged manurial treatments and known cropping histories for more than 100 years. Soil samples, taken periodically throughout their history, have been analyzed to follow changes in organic carbon content that can now be related to treatment.

Increasing the organic matter content of soils can benefit crop yields greatly, particularly in tropical areas. Some of the effects can be related to extra water-holding capacity, some to supplying and retaining plant nutrients in ways that cannot be readily mimicked by application of fertilizers, and some to improved soil structure. The effects of humus, which influences water and nutrient retention, should be differentiated from those of organic mulches, which are very important in decreasing erosion and surface evaporation.

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The Rothamsted Experimental Plots: Application to Tropical Sustainability Problems

Fertile soils and wholesome water supplies are two of a country's most important natural resources, and the well-being of future generations depends on their maintenance. Fertility develops slowly over many decades, but inept management can destroy it rapidly. Small, less obvious, but insidious changes can be equally damaging in the long term. Both rapid and slow changes can be quantified only in well-designed and rigorously controlled field experiments. If these experiments have contrasting treatments, those that cause least damage, both to soil fertility and the wider environment, can be readily identified. The best farming systems, which must also be economically viable, can then be recommended to farmers.

Soil fertility arises from complex interactions between the biological, chemical, and physical properties of soil, some of which are still imperfectly understood. However, the living plant integrates across all factors affecting its growth, and yields can be used to indicate whether soil conditions are optimum for crop growth. The data from the Rothamsted experiments in the United Kingdom illustrate concepts that can be used to provide guidelines for research in other climates, on different soils, and under a variety of farming systems.

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Legume Inoculants and Their Use

Unlike cereal crops, which must assimilate nitrogen as NO_3^- or NH_4^+, legumes can acquire nearly all their N from the atmosphere via a process called biological nitrogen fixation (BNF). Nitrogen derived from BNF is critical to sustain farm system productivity where capability to use N fertilizers is limited. The complex processes of BNF begin when a bacterium called Rhizobium colonizes and then infects the root system. Root nodule formation follows, and rhizobia within the nodule begin to reduce N_2 to NH_3 and synthesize amino acids. Energy for N_2 reduction and growth of rhizobia in this symbiosis is derived from oxidation of plant photosynthate. The amount of BNF is highly regulated by the health of the legume and by available N in the soil.

Rhizobia are usually inoculated on legume seed at planting to ensure the availability of large numbers of highly effective rhizobia to infect the roots. Inoculation technology is inexpensive, environmentally benign, and readily adaptable by farmers. Problems related to availability of inoculants, quality of inoculant products, and farmer awareness of the potential of the technology currently limit the adoption of the technology in many tropical countries and in the former Communist Bloc countries.

Does legume inoculation with rhizobia increase yield? How much N_2 do legume crops fix? Do legumes increase soil N availability? There are no simple answers. The answers depend upon the performance of rhizobia and BNF in the crop system, the complex interaction between plant and microbial genes, and the soil, climate, and management factors that influence the rhizobia and plant individually as well as their symbiotic relationship. In any sustainable agricultural system, the important factors and principles that determine legume BNF processes and performance must be understood. In tropical systems, special emphasis should be placed on understanding the native rhizobia populations and the soil management practices that influence legume BNF indirectly through impact on photosynthesis and crop yield potential. The factors that may control BNF can be determined for individual soils by using pot experiments to determine host-rhizobia genetic interactions and soil fertility influences (particularly P) on BNF.

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Phosphorus Sources, Utilization, and Increasing Efficiency

Phosphorus (P) is critically needed to improve soil fertility for sustainable crop production of arable soils, particularly the acid soils in developing countries. In recent years, some nonconventional P fertilizers such as phosphate rock (PR), partially acidulated PR (PAPR), and PR compacted with water-soluble P fertilizers have been tested as potential alternatives to conventional, water-soluble P fertilizers like single superphosphate (SSP), triple superphosphate (TSP), and diammonium phosphate (DAP). The relative agronomic effectiveness of various P fertilizer products is influenced by four factors: fertilizer properties, soil properties, management practices, and crop species. Water solubility is not the only criterion in selecting the most suitable P fertilizer. Under certain conditions, nonconventional P fertilizers can be both agronomically and economically effective in sustaining crop production. These products have high residual effects and cause less environmental degradation in industrial production. However, although production of these products requires much less energy than is needed for soluble P sources, transportation costs will be much higher per unit of P delivered to the farm because of their lower nutrient content.

Norman S.H. Chien
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International Fertilizer Development
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Water Solubility of Phosphorus Sources and Available Organic Phosphorus Forms in Tropical Soils

Most commercially available phosphorus (P) fertilizers contain 80%-90% of the total P in a water-soluble form. These products provide cost-effective materials with a high P nutrient content. However, due to the energy requirements and environmental effects related to their production, there is some concern as to how much water-soluble P is required by plants for maximum economic production. Soil factors (e.g., pH, P-fixation capacity, soil P level, moisture, temperature) and physical factors (fertilizer particle-size and application method), and crop species (particularly the duration of growth) affect water-solubility requirements of P fertilizers. Previous research indicates that there are differences in the solubility requirement for temperate and tropical cropping conditions.

The significance of soil organic P in crop production is greater in the tropical soils than in temperate soils. Transformations of soil organic P through interactions with soil minerals, soil organic matter, organo-minerals, and microbial uptake are some of the factors affecting the availability of soil organic P to plants. Additional research related to the organic P turnover cycle and its importance in a sustainable agricultural system is needed.

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Water Harvesting Systems in Semiarid Areas

Two factors are clearly common to all semiarid areas: a limited supply of water and a serious erosion potential. Conservation of water and soil resources are important elements in productive agriculture and major considerations in semiarid areas.

Water harvesting refers to techniques of collecting rainfall runoff to provide livestock and people with drinking water and to supply water for growing crops. This can help make the drought-prone areas more sustainably productive, while conserving natural resources.

A number of water harvesting systems have been developed to suit specific regions, crops, and rainfall patterns, and many variations in the techniques of water harvesting are possible. Some of the most commonly used techniques are systems with external catchment areas. Water-spreading techniques deliver water from intermittent streams or surface runoff in sloping areas onto more level land, which can be cropped or grazed. Other systems may collect runoff by bunds built on the catchment area and divert the water to lower-lying croplands or ponds. Among the techniques that utilize within-field catchment or in situ rain harvesting are microcatchments, contour bunds, and strip cropping.

In water harvesting projects in the semiarid high plains of Mexico, water for livestock and human consumption was collected using rain traps, pistachio trees were grown in individual microcatchments, and forage crops were grown using contour bunds with a 2:1 ratio of catchment area to cultivated area.

Rainfall collection and water concentrating have considerable potential for small farmers in remote regions where rainfall is low and suitable supplies of groundwater are lacking. Within-field systems are less risky, less labor intensive, and frequently are more adoptable than external catchments. Water collection systems markedly decrease the risk involved in semiarid agriculture; they also serve to control soil erosion, recharge aquifers, and help make other agri-inputs more profitable.

Gildardo Carmona
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An Overview of Composting Principles and Applications

Composting in some form has been used throughout sedentary agriculture as a method to stabilize and decrease the volume of farm residues and to return the nutrients contained in these materials to the soil. With modern scientific study, composting has advanced from a primitive art to commercial technology. When practiced properly, composting controls or optimizes microbial activity to decompose and stabilize the organic materials. A successful composting operation depends on the proper management of oxygen availability, nutrient balance, moisture content, and other related factors. The Tennessee Valley Authority's National Fertilizer and Environmental Research Center is working with universities and private industry to research, demonstrate, and promote composting as a scientific and cost-efficient part of resource management that contributes to sustainable agriculture and pollution control.

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Development and Promotion of More Sustainable Agronomic Practices

A "sustainable agriculture" approach to problems must be site-specific to have utility or validity. My recent research has addressed the problems in rainfed rice production systems of the very poor farmers of eastern India. Inefficient and little use of chemical fertilizers, random transplanting, little use of manures, and inadequate pest control are their major constraints. As for any research with a sustainability approach, the changes in farmer practices need to be appropriate, i.e., they must be simple, economical, socially acceptable, environmentally safe, agronomically efficient, and in this case appropriate for women, the main transplanting force.

One approach has been to use rice hull ash (RHA) to supply silica to rice seedlings in the nursery. The RHA-fertilized plants are more resistant to stem borers and to rice blast, two major rice pests. Decreasing the use of pesticides helps to maintain beneficial insect populations, decreases exposure of workers to health risks, and decreases environmental pollution. The rice hull stoves are efficient devices that utilize a waste while decreasing wood and manure burning.

Another approach has been to demonstrate that line transplanting enables farmers to achieve multiple benefits. By facilitating deep point placement of urea briquettes, line transplanting nearly doubles the N efficiency over conventional N application methods. This endeavor illustrates basic concepts of sustainability: generally, sustainability requires the application of known techniques that provide multiple benefits and a great degree of interaction with other management factors. With the better techniques, transplant seed is decreased by 35%, fertilizer runoff losses are eliminated, and weeding and spraying operations are facilitated. The fertilizer efficiency is practically doubled by deep point placement.

Narayan K. Savant
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Assisting Farmers to Adopt More Sustainable Practices

"The problem is not the farmer, but her doctor" is an expression that sheds light on several fundamental aspects of the transfer of more sustainable agricultural technology. First is the realization that farmers around the globe are ahead of researchers or are the main researchers where the development and testing of sustainable practices are concerned. Second is the fact that women continue to play a pivotal role in most agricultural systems, a fact that should be carefully considered in the design and delivery of agricultural technology. Finally, most new technology has the potential to generate both good and bad effects, depending upon one's perspectives.

A number of different models have been proposed and analyzed for developing, testing, and transferring improved agricultural practices. Most recent attempts involve the farmer, but few credit the farmer as a vital resource. Most of the fundamental processes that constitute today's definition of "sustainable agriculture" have already been observed in traditional farming systems (e.g., water "harvesting," soil conservation, integrated pest management, nutrient cycling, and systems diversity). We academicians have shown ourselves to be relatively poorly trained or motivated at learning from successful (sustainable) indigenous systems.

Agricultural researchers and extension workers have done somewhat better at teaching than at learning, and often we have failed to recognize the fact that in many societies women are the farmer-targets of our messages. The price we pay for this error is often significant in terms of sustainable agricultural technology, where studies have demonstrated the potential for appealing to inherent female instincts for nurturing. Many of the farmers' decisions on natural resource conservation and management include values on time and selflessness that often show gender differences. These differences may be related to the observation that many tropical farming systems offer more promise for sustainability and enhancement because there has been, to date, less human intervention aimed at dominating natural processes.

The ways in which a farming society views soil, land, and other natural resources (renewable and nonrenewable) are almost certainly a key as to how sustainable technology can and should be developed, packaged, and delivered. This is especially true because sustainable practices include not only specific choices in pest control and soil amendments, but also complex and somewhat

abstract underlying principles of soil conservation and responsible resource management. Most of the terms used by scientists to describe sustainable aspects of soil "health" and "quality," such as tilth, friability, and productivity index, are properties whose value is most meaningful in the context of local farm communities. Our sustainable agricultural efforts must increasingly balance sociological, economical, and biological sciences because rural and societal values are basic to promoting the product.

Farmers are often the best teachers of other farmers, because they appreciate the timing, risk, management demands, and family values that a neighbor will weigh in considering a new recommendation. Our project relies heavily on our farmer-members for participation in economic studies and in field demonstration events. The optimum means of utilizing farmers in sustainable agriculture research and extension is by necessity highly location-specific .

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Integrating Indigenous Knowledge Systems and Institutional Research Technologies Toward Sustainable Food Production

Increasing pressure for food production due to the rapidly growing population and increased reliance on modern, high-input technologies has led to the gradual disappearance of indigenous knowledge systems (IKSs) related to food production and resource conservation. Recent research on IKSs indicates that they are numerous, highly sophisticated, and complex, reflecting generations of careful observation of specific agroecological environments. Thus, a study has been conducted with an objective to (1) record IKSs and (2) integrate IKSs and station research technologies.

Several specific examples of IKSs related to food production and resource conservation were recorded directly from farmers belonging to three South India villages. The IKSs were recorded using four stages of farmer participation:

1. Transect stage: Transects were drawn by walking through the villages to demarcate the agroecological zones and their biophysical environments.
2. Participant observation stage: iKSs pertaining to food production and resource conservation were recorded during this stage.
3. Unstructured interaction stage: Participatory meetings were conducted among the various groups of local farmers to discuss the rationale behind the use of IKSs.
4. "Emic" instrumentations stage: An emic instrument was used to identify the extent that the IKSs are used "as perceived" by the local farmers.

A methodological framework that incorporates IKSs and need-based station research technologies has been developed in collaboration with the farmers. The framework has been built upon IKSs, needs as prioritized by various groups of local farmers, and biophysical conditions of the villages. The framework would be of high practical value to farming systems research and extension practitioners, especially while conducting on-farm research programs.

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Instilling a Sustainability Perspective in Research and Extension Activities

Sustainability rests on the principle that we meet the needs of the present without compromising the ability of future generations to meet their needs. Therefore, stewardship of both natural and human resources is of prime importance. To achieve or move toward sustainability as a goal means that we deal with agriculture as an economic, ecological, and social system. A systems approach implies interdisciplinary efforts in research and education, and this requires the input of researchers, consumers, farmers, farm workers, and policymakers.

Sustainability works with nature as much as possible, so it is both diverse and site-specific. Important concepts involved include biological diversity, soil management, efficient use of inputs, farmer goals, and family life styles.

Also important are food and agricultural policy, land use, labor, and rural community development.

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