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FARMING SYSTEMS RESEARCH/EXTENSION
AND THE CONCEPTS OF SUSTAINABILITY

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Abstract

Farming Systems Research and Extension (FSR/E) has strongly influenced the direction of agricultural development over the past two decades. Involving farmers, change agents and researchers, this participatory approach to technological improvement has evolved as an efficient means to develop individual components and more integrated systems that are uniquely suited to specific biophysical and socioeconomic conditions. Farmers with similar conditions and for whom specific recommendations are appropriate are grouped, in FSR/E, into identifiable Recommendation Domains. The technologies recommended conform with the biophysical and socioeconomic constraints that create environments within the domains, based on the philosophy that new technologies must conform with the environments where they will be used because most farmers are unable to modify their environments to meet the needs of new technologies. This characteristic differentiates FSR/E from the approach of developing conventional technologies to dominate environments through use of machinery, chemicals, irrigation and other capital-intensive inputs.

The philosophy of sustainable agriculture is gaining ground in a world becoming acutely aware of finite fossil fuel resources and adverse impacts of agriculture and other industries on the environment. In spite of substantial advances in productivity through applications of fertilizers, pesticides, and irrigation, we are learning that inappropriate or excessive use of these inputs can have unexpected and undesirable effects on the environment, natural ecosystems, and the world's human inhabitants. In order to develop the systems that will provide for our needs without endangering the quality of life of future generations, we must concentrate on an efficient use of renewable resources that are available within the immediate production environment. We need to reduce fossil fuel use to minimum essential levels. We must develop technologies that conform more closely with the environments where they will be used. The urgency associated with coming to grips with the problem is becoming more evident every day. These necessities precisely coincide with the capabilities of the FSR/E approach.

FSR/E practitioners work with families who live on the land and are acutely aware of their surrounding environments and how they are influenced by cropping and farming practices and systems. Because farmers participate in the development and testing of alternatives, their evaluation criteria will be used for screening. These may differ from the narrower and often misleading criteria used by researchers trained in specific disciplines. This aspect, in itself, enhances the efficiency and effectiveness of the technology development and adoption process.

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When the farmers' concerns and resource base are more explicitly taken into account, technologies thus developed are more readily adapted to the farmers' environments. Perhaps most important, FSR/E on-farm research and technology evaluation methods have proven efficient for screening and selecting technologies that conform to the divergent environments found on farms throughout the world.

Introduction

Farming systems research and extension methods have been widely tested and applied over the past two decades in a range of ecological and economic circumstances. Client participatory and location specific in nature, this approach has extended the methodological resources available to administrators in public institutions who are concerned with the application and credibility of recommendations from research. Holistic and interdisciplinary in its focus on total systems, FSR/E takes into account the multiple goals of the farm family as well as the economic and resource situation in which the farm operates. When we consider the time dimension within which the family makes decisions and plans for the future, the long-term sustainability of production and profit become central to system design (Francis and Hildebrand, 1988).

There is little agreement about precisely what is meant by "sustainable agriculture". Growing concerns about the finite fossil fuel resource base upon which modern agriculture depends and about the quality of our environment, bring new focus to the philosophy of sustainability. The perspective in which we are developing this philosophy was eloquently reviewed by Lockeretz (1988). Given the immediate and continuing needs of an expanding population for food, as well as concerns about resources and the environment, a definition given by Harwood (1988) seems appropriate:

... an agriculture that can evolve indefinitely toward greater human utility, greater efficiency of resource use and a balance with the environment that is favorable both to humans and to most other species.

The importance of the fusion of sustainable agriculture philosophy with the methods and experiences from farming systems research and extension is amply illustrated by the focus and topics of the 1989 symposium in Fayetteville. In addition to recurring themes of productivity, profitability, farmer participation, and institutional development, the papers this year reflect a clear priority on resource issues and environmental quality. This paper describes our current awareness of complex issues in agricultural development and how an emerging consensus on sustaining agricultural production is impacting the mainstream of research and extension.

FSR/E Methodology and Sustainable Agriculture

The client participatory nature of FSR/E enhances the capability of research and extension organizations to incorporate farmers' goals, resources, concerns with their own future, and their experience into the technology generation and diffusion process. These characteristics all influence the production environments, and the farming systems, found on different farms. It is because of the diverse nature of these environments that technologies need also to be diverse. FSR/E methodology has recognized this need -- it is suitably expressed in the commonly used term, Recommendation Domain. In responding to the concerns for a more sustainable agriculture, more emphasis must be placed on developing genetic materials and farming practices that fit within the biophysical and socioeconomic environments of different farming systems. This will necessarily be based on a fuller understanding of these environments and in on-farm research to evaluate technology by environment interactions. This in turn will depend on enhanced multidisciplinarity, another of the basic facets of FSR/E methodology.

Sustainable agriculture will require augmented technology innovation and diversity. The development of a wider array of genetic materials and farming practices is encouraged by on-
farm research and evaluation early in the technology development process. In this process, screening is usually initiated under controlled conditions where researchers feel they are better able to detect any differences in their treatments or materials. Acceptance and rejection at this stage determines which of the potential new technologies receive further evaluation and which are rejected. Because of environment by treatment interaction, treatments that respond well under controlled conditions (and usually in superior production environments) may not respond well under environments more representative of farmers' conditions. But also, and with potentially more serious effects, treatments that manifest less potential under the favorable conditions usually found on experiment stations, and are rejected for further evaluation, may well be those which would be superior under real farm conditions. Hence, early evaluation of potential new technology on farms and under real farm conditions, a basic feature of the farming systems approach, can help assure more technology diversity and a more sustainable agriculture in the future.

As compared with conventional, capital intensive agriculture, it is widely agreed that sustainable agriculture is more information- and management-intensive. For sustainable technology to be adopted, it will have to fit into the management capabilities of farm managers, and within their resource base, in each recommendation domain. Again, the multidisciplinary procedures used in the farming systems approach are appropriate to helping researchers and extension workers understand the capabilities of farmers in their research domains. Rapid reconnaissance surveys or "sondeos", a well known component of farming systems methodology, were developed to help understand farmers and their conditions. The participation of farmers and persons from several disciplines in on-farm research also helps in understanding farms and farmers.

The longer term desires of society do not necessarily coincide with short term needs of individual farmers. Farmers are concerned with family survival and welfare and may use practices and resources in a way that from society's perspective is non-sustainable. Farming systems methodology can contribute in two ways to help alleviate these conflicts. First, by understanding the needs of the family, practitioners are better able to develop technology that satisfies farmers' needs while at the same time, using scarce resources more efficiently. Secondly, policy makers can take advantage of the knowledge of farming systems teams to help devise policies more in harmony with society's needs, while at the same time providing the appropriate policy incentives to encourage farmers into using more sustainable practices.

A more sustainable agriculture will not be achieved just because society desires it. Means must be derived for efficiently achieving the diversity of location-specific technology necessary to support it. Farming systems methods are cost- and time-efficient in this regard. The conventional method for developing new technology requires several years of evaluation and screening under controlled conditions before it is submitted to farm conditions. As explained above, after several years of testing, this process can result in

1) the selection of technology by researchers which does not do well under real conditions and is therefore rejected by farmers,

2) the rejection of technology by researchers because it did not perform well under controlled conditions, but which might have done well under real conditions, as well as

3) the release of a successful technology.

Designing and developing technology for well characterized socioeconomic and biophysical conditions, followed by early on-farm testing to minimize the rejection of useful technology, can reduce the time span from conception to adoption and increase the adoption success rate. Coupled with the fact that farmers supply a significant amount of research resources for on-farm research (Franzuebbers et al., 1988), means that FSR/E is an efficient approach from both time and cost perspectives.
Sustainable Agriculture

Farming systems could be viewed on a time spectrum as having important past, present, and future dimensions. All that has occurred in past cropping seasons -- choice and management of specific crop species, incorporation of animal or green manure, cropping intensity, soil conservation practices, climatic conditions -- has predisposed a specific field as well as a farm with certain potential for productivity in the current year. Events of past farming seasons have contributed to the experience base that influences management in the current year. The dynamic cyclical and linear changes in one field could be called the "progressive biological sequencing" of practices and biological consequences that occur in that field as a result of a given management strategy (Figure 1, Francis et al., 1986). As the management of this one field influences practices in other parts of the farm, the interactions that take place are also managed by the astute operator; this could be called the "integrative farm structuring" in that farming operation (Figure 2, Francis et al., 1986). This is the space and time continuum within which farmers operate and decisions are made.

Crop and animal patterns are based on family goals, land and other resources available, labor, and production potential of the farm. These are dimensions of the production system that are quantified or otherwise made explicit in the methodology of farming systems research and extension. Decisions made for the current year not only affect immediate farming success in terms of food, income, profitability, they influence the potential for future productivity of the land. In a real way, past practices and current decisions determine to a large extent future sustainability.

How well the farm family can sustain production and profit into the future will depend on how well the goals for food and income can be reached within the short-term land, labor, and other resource constraints of the family. There may be trade-offs between short-term profits and long-term productivity, for example in the use of all land for cash crops versus some area in green manure crops for providing nutrients for future crops. Choice of some sub-optimum crops in terms of immediate profits may lead to greater long-term productivity or sustained profit or less variation in family income. Families living too close to the edge of economic survival in both developed and developing countries may not have the luxury of considering long-term productivity of soils or the total farm. Finally, how we evaluate the sustainability, of practices or systems, depends on how this philosophy is defined. Sustainable for how long, and under what assumptions about resources and quality of the environment? The methods developed in a farming systems context are uniquely suited to provide some of this information and focus.

Problems with Definitions

The broad definitions given in the introduction provide a useful philosophical framework within which to consider specific practices and systems. Confusion surrounding terms was described by Lockeretz (1988), and this is not likely to be resolved due to the range of people and organizations embracing the term if not the concepts described here. Choice of this term is complicated by the fact that it is too good; everyone appreciates that agriculture must be sustainable. But we differ in the interpretations of conditions and assumptions under which this can be made to occur. And we differ in time frames. One mechanistic definition was advanced to help researchers and farmers choose specific practices as components of production systems to lead to specific goals (Univ. Nebraska, 1987):

A sustainable agricultural system is the result of a management strategy which helps the producer to choose hybrids and varieties, soil fertility packages including rotations, pest management approach, tillage methods and crop sequence to reduce costs of purchased inputs, minimize the impact of the system on the immediate and the off-farm environment, and provide a sustained level of production and profit from farming.
This definition lacks specificity in terms of time frame, resource availability, and environmental impact, all of which must be considered if we are concerned about evaluating specific technologies and how "sustainable" certain systems will be when comprised of these pieces of technology.

**Evaluation Criteria**

Not only do we have problems defining sustainability, we have no useful means of measuring it -- how much more sustainable is one practice or system than another?, for example. Furthermore, we have not incorporated appropriate evaluation criteria into our research and extension procedures. Among other shortcomings is the failure to take into account time and resource dimensions. One of the most common evaluation criteria for measuring the effect of alternative technologies on crops is kg ha$^{-1}$. The use of this criterion implies that 1) quantity produced is the important result of the production process, 2) land is the most limiting resource, and 3) the length of the production process is not relevant. Economists usually consider net income ha$^{-1}$ as the important criterion. This implies that quantity, itself, is not important, but the difference between how much it is worth and how much it cost to produce. However, this criterion still implies that land is the most limiting resource and that the length of the production process is not relevant. To compare two different kinds of rotations would require the incorporation of the length of the rotation in years. For example, yield or net income per hectare averaged over the number of years the rotation lasts could be used.

These relatively common criteria, however, do not improve our measures of sustainability nor our capabilities to compare the sustainability of different systems. If we are concerned with nitrate contamination of ground water, for example, we will need to begin to use such criteria as kg per unit of nitrate leached or net income per unit of nitrate leached. Another criterion might be kg per unit of toxic chemical applied. In either of these cases, an increase in the criterion would presumably be associated with more sustainability. But time is still not included in either case. If we are concerned with the depletion of tropical rain forests, perhaps a useful criterion would be kg per ha of forest destroyed. Comparing two systems with this criterion would allow us to choose the one which either produced more for the same amount of destruction or produced the same amount with less forest destruction.

Even with these criteria, however, we have still not solved the problem of incorporating the time frame into the measure of sustainability. If more sustainable means longer, then we certainly must be able to measure longevity. A paper being presented at this symposium (Hildebrand and Ashraf, 1989) reports an unsuccessful attempt to do this.

**From Philosophy to Management Practices**

Although sustainable agriculture is considered a philosophy to guide technology development and the design and implementation of resource efficient farming systems, in practice this means the choice of specific inputs, practices or management options that will contribute to the overall goals. The component technologies or practices must be sorted out in relation to the natural and cropping environment, the goals of the farm family, the resource base within which the farm is managed, and society's goals with respect to the use of natural resources and the importance of respecting the well being of future generations.

Because of the climatic and farm location specificity of practices and crop/animal systems, it is difficult if not impossible to generalize about farming practices that meet the criteria described above. Yet there are general approaches to development of technology, and examples of specific practices that help to illustrate both philosophy and principles of sustainable agriculture (Francis, 1989; Francis and Youngberg, 1989).
Crop varieties and hybrids that include genetic tolerance or resistance to insects, plant diseases, drought, and extremes in temperature are especially useful in reducing input costs and risks of crop loss. Different maturities of crops within species provide more flexibility for planning cropping and crop/animal integrated systems, for example by avoiding drought, making best use of available rainfall, providing forage as well as grain, or fitting a specific niche in a farming system. Genetically diverse varieties or hybrids often provide greater biological buffering to resist unexpected variation in climatic conditions.

Sustainability of systems and reduced production costs may be promoted by greater use of biological or cultural control methods for insects, diseases and weed problems. Integrated pest management makes increased use of information as a substitute for all or part of the purchased pesticides to control unwanted species in the field. Crop rotations can play a major role in improved systems. Alley cropping and other agroforestry systems can make more efficient use of the total natural resource base throughout the year, and protect the soil against wind and water erosion. The increased diversity of these systems helps to attract and preserve biological diversity as well, often giving an enhanced potential for biological control of pests. Rotations, as well as carefully designed agroforestry patterns can promote nutrient cycling and efficiency of resource use. These can be coupled with reduced tillage to save fuel, maintain crop residue cover, and minimize potential for soil erosion. Reduced chemical applications and tillage often will enhance soil arthropod populations and activity.

Diversity of crop and animal species and products from the farm can further buffer the economic returns to land, labor, and capital. When maximum attention is paid to value-added products, this economic stability or sustainability can be enhanced even further. Feeding non-marketable grains or crop residues to livestock before sending the end product to market can give higher returns to inputs, and manure can be returned to the land. With non-chemical management, organic food channels provide higher prices for products and potentially greater return to the grower. New avenues for marketing, consistent with farm location, time available, and family goals, can further enhance the value of farm produce. If farm related industry is promoted, both on the farm and in nearby communities, it is possible to enhance both the sustainability of farms and the community infrastructure that is essential for their long-term viability.

Precisely which practices fit into each operation and which of the above really fit into any specific farming system depends entirely on the local resources, management options available, ability of the farm operator and family to implement the changes, and whether these help the family to meet long-term goals. There is growing concern about health and safety on the farm, and this is leading to research and testing of a wider range of alternative practices. In any case, the methods of FSR/E are uniquely suited to the screening of potential alternatives, the search for other options suggested by farmers, and the practical testing of these practices against current management approaches. In many locations, a limited research base and few recommendations are available for some of these practices. The methods outlined above and available in FSR/E are well recognized as a viable route to evaluate applications of new technologies or practices in a real world situation while farmers are gaining experience with them at the same time.

There is growing literature about the critical role that concerns with sustainability will play in future decisions in the agricultural industry. There are numerous examples of environmental impacts of current systems in symposia publications from the past decade (Bezdicek, 1984; Edwards et al., 1989; Power, 1987). Crop protection alternatives without chemicals or with drastically reduced applications have potential to significantly reduce the total amount of pesticide introduced into the environment (Bird et al., 1989; Grainge and Ahmed, 1988; Liebman and Janke, 1989; Ware, 1980). Soil fertility potentials and economics in reduced chemical fertilizer systems have been described and documented (King, 1989). Finally, the conversion to systems with lower inputs has been explored and quantified by a number of researchers and farmer collaborators (Andrews et al., 1989; Kirschenmann, 1988). Recently the
National Academy of Sciences published a National Research Council book on alternative agriculture (NAS, 1989). This emerging literature on alternative management systems gives greater confidence to extension and development people in the field who are promoting systems that depend on reduced inputs. The application of FSR/E methods in the testing and widespread demonstration of these techniques will provide even more information on how they apply in a wider range of circumstances. Environmental and resource issues will be better understood as educational activities are focused on farmers as well as the general public.

**Conclusions**

No one would advocate a "non-sustainable agriculture"! On the other hand, even though we are not able to define nor measure "sustainable agriculture" the concerns which it expresses are here to stay. We must become more concerned with our biosphere and with the well being of future generations. This means we must develop agricultural practices that are less damaging ecologically and more efficient in the use of both renewable and non-renewable natural resources. As developers of agricultural technologies in the broadest context, we must work with policy makers and heed society’s concerns as reflected in policies they make. We must become attuned to the world around us and accept the challenges which are forthcoming. Farming systems research and extension methodologies are uniquely suited to this task. Let's get on with the work.

**References**


Figure 1 Conceptual pattern of dynamic cyclical and linear changes in one field crop environment as a result of successive crops and management decisions. (From Francis et al., 1986)

PROGRESSIVE BIOLOGICAL SEQUENCING

Figure 2 Conceptual pattern of interactions and integrations of primary crop and animal enterprises on a resource efficient farm. (From Francis et al., 1986)