The Evolution of Sustainable Agriculture in the United States: A Recent Historical Perspective

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Abstract

Soon after World War II, during the late 1940's and early 1950's, many U.S. farms began to shift from mixed crop-livestock operations to highly specialized, monoculture-type, cash grain production systems. This occurred because grain prices were high, energy costs were low, high-yielding varieties were available, credit was easily obtained, and risk was low because of government subsidies and support programs. Livestock virtually disappeared from these systems and were confined to feedlots. Without crop rotations and animal manures to maintain soil productivity, farmers had to increase their inputs of chemical fertilizers and pesticides, Intensive tillage and the lack of appropriate conservation practices often resulted in excessive soil erosion and a decline in soil productivity. Other problems associated with this type of agriculture are the pollution of surface water and groundwater by agrichemicals. Consequently, there has been a growing public concern about adverse impacts of agriculture on the environment and on the safety and quality of food. Questions have also been raised about the sustainability of U. S. agricultural production over the long-run.

Beginning in the late 1970's and continuing through the 1980's to the present, there have been some significant initiatives by the federal government to ensure that U.S. agriculture is an environmentally-sound, resource-conserving, and economically-viable enterprise that produces safe arid nutritious food for consumers. Among these were the 1978 USDA report on "Improving Soils with Organic Wastes"; the 1980 USDA "Report and Recommendations on Organic Farming"; the 1985 Farm Bill that established the Low-Input/Sustainable Agriculture Research and Education Program or LISA; the 1989 National Research Council Report on "Alternative Agriculture", the 1990 Farm Bill that established criteria for sustainable agriculture, and authorized the development of national certification standards for organically-grown agricultural products; the 1993 National Academy of Science's National Research Council Report on "Pesticides in the Diets of Infants and Children"; and the 1993 tripartite declaration and commitment by USDA, USEPA, and USFDA to develop methods and strategies to reduce pesticide use by farmers, and to promote sustainable agriculture in the United States.

Introduction

For the first half of this century, most farms in the United States were mixed crop-1ivestock operations. Farmers produced forages and feed grains for their animals through long-term crop rotations that required minimal purchased inputs. Soil productivity was maintained by crop rotations, including nitrogen-fixing legumes, and the return of crop residues and animal manures to the land. Few pesticides were used. Weeds, insects and plant diseases were controlled mainly through crop rotations, mechanical cultivation, and biological means such as natural predators.

Some profound changes began to occur in the late 1940's and early 1950's when U.S. farmers began to shift from mixed crop-livestock farming to highly specialized cash grain, monoculture production systems. Monoculture is the practice of growing the same crop on the same land through at least two crop cycles. This is the system that is most used for the production of wheat, corn, soybeans, cotton, sorghum and sugarcane in the United States. The three principal factors that enabled farmers to adopt monoculture practices were (a) the development of large-scale mechanization for tillage, planting and harvesting, (b) improved, high-yielding varieties, and (c) the availability of low-cost chemical fertilizers and pesticides (Power and Follett, 1987). Moreover, because of favorable commodity prices, farmers were able to significantly increase their net returns.

Another important factor that accelerated the shift toward monoculture cash grain production systems was that government programs and farm subsidies greatly reduced the risk of specialization. However, this also encouraged the separation of feed grain production from the livestock component, which was rapidly transformed into a feedlot industry. This resulted in the decline of two very vital soil and water conservation practices, i.e., the return of animal manures to the land and the rotation of grain crops with grasses and legumes. Consequently, farmers that specialized only in cash grain production, often monoculture systems, then had to increase their inputs of chemical fertilizers and pesticides to compensate for the lost benefits of crop rotations.

Thus, for most of four decades U.S. agriculture has substituted machinery, pesticides, chemical fertilizers, irrigation and energy for crop and livestock diversity, labor, land and traditional farm management. This in turn, has led to many of the current problems and growing concerns about U.S. agriculture, including excessive soil erosion, loss of soil productivity, pollution of surface and ground water by sediment and agrichemicals, health risks and environmental impacts of pesticides, and food safety and quality. It has also raised serious questions about the long-term sustainability of our farming systems.

This paper discusses some recent developments in the sustainable agriculture movement in the United States and some institutional and policy initiatives that seek to address these problems and concerns.

Alternative Agriculture and Related Terminology

A number of terms and definitions have emerged in recent years that refer to a spectrum of low-chemical, resource- and energy-conserving, and resource-efficient farming methods. For example, words such as “alternative,” “biodynamic,” “biological,” “eco-agriculture ecological” “natural” “regenerative resource efficient” and “sustainable” are specific terms used by certain advocates and groups to refer to various alternative agricultural production practices and technologies that, they feel, arc essential to the development of long-term sustainable farming systems. The more general terms that have come to be most widely used during the last decade are “alternative sustainable” “organic” and “low-input.” Many who have been seeking alternatives to conventional agriculture, tend to view the term “alternative” as one which encompasses most, if not all, of the others (NRC, 1989).

The word “organic” was once considered to be a generic term representing these low-chemical, resource-efficient methods of farming (Youngberg et al., 1984). This, however, is no longer the case. The word organic now is used almost exclusively to refer to the non-use of chemical fertilizers and pesticides as a requisite for compliance with state certification standards for organically-grown foods. Therefore, the term “organic agriculture” is increasingly used within a legal context for the purpose of certification.

Soil Erosion and the Loss of Productivity

Today in the United States, soil erosion by wind and water, the associated decline in soil productivity,[1] and the adverse effects on water quality continue to be our most serious agricultural and environmental problems (Larson et al., 1990). Much of this has been the result of improper and exploitive farming practices related to intensive cash grain production. Brown and Wolf (1984) concluded that the soil erosion crisis must be considered in a global context because the production, distribution, and consumption of food is part of the global economy. They estimated that the mean annual loss of topsoil worldwide is about 0.7 percent. This is of great concern because the loss of productivity may not easily be restored, even with application of chemical fertilizers. Studies have shown that when the topsoil is removed, or where it has been severaly eroded, crop yields are from 20 to 65 percent lower compared with non-eroded soils (Langdale et al., 1979; Massee, 1990).

[1]The U.S. Department of Agriculture (USDA, 1957) has defined soil productivity as: “The capability of soil for producing a specified plant or sequence of plants under a defined set of management practices. It is measured in terms of outputs or harvests in relation to the inputs of production factors for a specific kind of soil under a physically defined system of management.”

Figure 1 illustrates an important relationship that is often overlooked, i.e., for most agricultural soils, degradative processes such as soil erosion, nutrient runoff losses, and organic matter depletion are going on simultaneously with the beneficial effects of conservation practices such as crop rotations, conservation tillage, and recycling of animal manures and crop residues (Hornick and Parr, 1987). As soil degradative processes proceed and intensify, soil productivity decreases concomitantly. Conversely, soil conservation practices tend to slow these degradative processes and increase soil productivity. Thus, the potential productivity of a particular soil at any point in time is the result of on-going degradative processes and applied conservation practices. Generally, the most serious degradative processes are soil erosion and associated depletion of plant nutrients and organic matter.

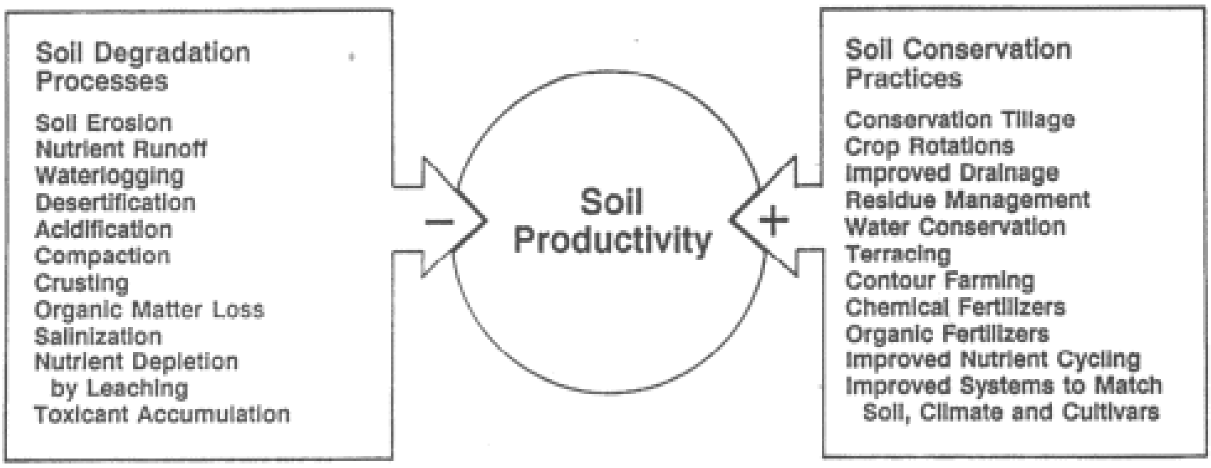

Figure 1. Relationship of Soil Degradative Processes and Soil Conservation Practices (Hornick and Parr, 1987).

On our best agricultural soils - that is, gently sloping, medium-textured, well-structured, and with a deep, well-drained profile - a high level of productivity can be maintained by relatively few, essential conservation practices that readily offset most degradative processes. However, on marginal soils of limited capability, such as steeply sloping, coarse-textured, poorly-structured, depleted of nutrients, and with a shallow, poorly-drained profile, soil conservation practices must be maximized to counteract further degradation.

Thus, a truly sustainable farming system is one in which the beneficial effects of various conservation practices are equal to or exceed the adverse effects of degradative processes. Organic wastes and residues offer the best possible means of restoring the productivity of severely eroded agricultural soils or of reclaiming marginal soils (Hornick and Parr, 1987; Parr and Hornick, 1992).

The Concept of Sustainable Agriculture and Alternative Agriculture

Sustainable agriculture is increasingly viewed as a long-term goal that seeks to overcome problems and constraints that confront the economic viability, environmental soundness, and social acceptance of agricultural production systems both in the U.S. and worldwide. While there are many definitions of sustainable agriculture, most of them encompass the same elements of productivity, profitability, conservation, health, safety, and the environment, differing only in the degree of emphasis. Furthermore, “sustainable” implies a time dimension and the capacity of a farming system to evolve and endure indefinitely (Lockeretz, 1988).

The Agricultural Research Service (USDA) defines sustainable agriculture as: Agriculture that for the foreseeable future will be productive, competitive and profitable, conserve natural resources, protect the environment, and enhance public health, food quality, and safety.

The U.S. Congress (1990) in drafting the 1990 Farm Bill defined sustainable agriculture as: An integrated system of plant and animal production practices having site-specific application that will, over the long-run:

- Satisfy human food and fiber needs,
- Enhance environmental quality and the natural resource base,
- Make efficient use of nonrenewable resources,
- Utilize natural biological cycles and controls,
- Improve the economic viability of farming systems,
- Enhance the quality of life for farmers and society as a whole.

The ultimate goal of sustainable agriculture is to develop farming systems that are productive and profitable, conserve the natural resource base, protect the environment, and enhance health and safety (all of this over the long-run) according to the National Research Council (NRC, 1989). Alternative agricultural practices provide the best means of achieving this goal. The National Research Council defined alternative agriculture as a system of food and fiber production that applies management skills and information to reduce input costs, improve efficiency, and maintain production levels through such practices and principles as:

- Crop rotations in lieu of monocultures,
- Integrated crop/livestock systems,
- Nitrogen fixing legumes,
- Integrated pest management,
- Conservation tillage,
- Integrated nutrient management,
- Recycling of on-farm wastes as soil conditioners and biofertilizers.

It is also important to note that the single most important component of a sustainable farming system is skilled management. The relationship between sustainable agriculture and alternative agriculture is shown in Figure 2.

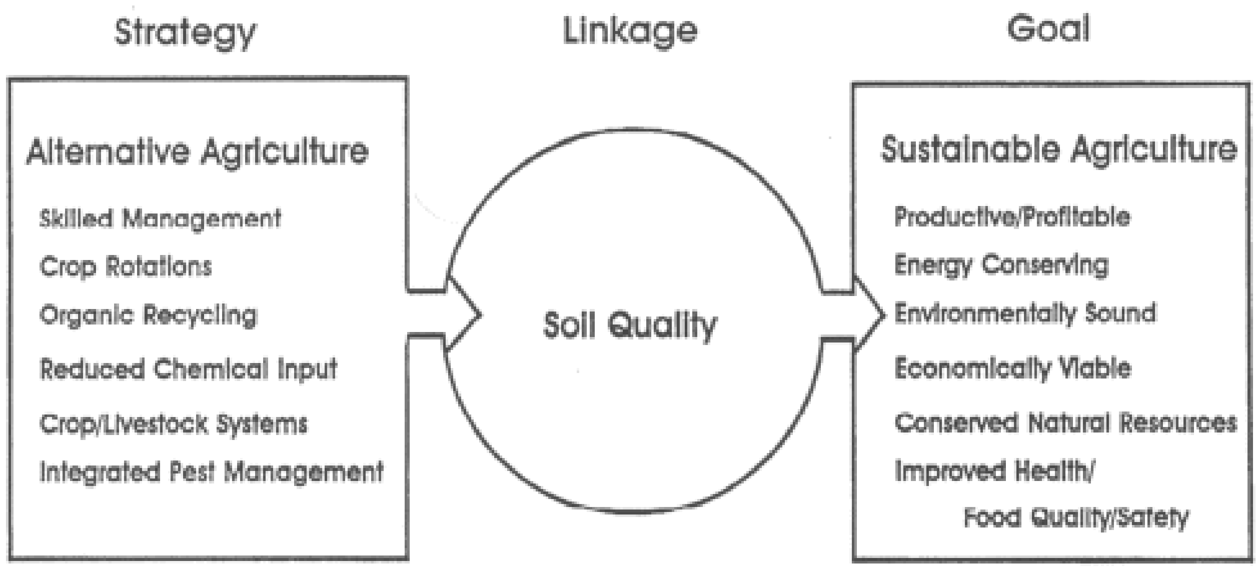

Figure 2. A Conceptual Diagram That I]lustrates How the Attributes of Soil Quality Provide a Link between the Strategy of Alternative Agriculture and the Ultimate Goal of Sustainable Agriculture (Parr et al., 1992).

Alternative agriculture seeks to optimize the use of internal production inputs (i.e., on-farm resources) and skilled management in ways that provide acceptable levels of sustainable crop yields and livestock production, and result in economically profitable net returns (Parr et al., 1990; Reganold et al., 1990). This approach emphasizes such cultural and management practices as crop rotations, use of animal and green manures, and conservation tillage to control soil erosion and nutrient losses.

In the United States, achieving a more sustainable agriculture has become the ultimate goal. How we achieve this goal will depend on creative and innovative conservation and production practices that provide farmers with economically-viable and environmentally-sound alternatives or options in their farming systems. While low-input/sustainable farming systems may be feasible in developed countries, it is likely that inputs in many developing countries will have to be increased substantially to raise the production potential above a subsistence level before agricultural sustainability can be achieved.

The Concept of Soil Quality

Various physical, chemical, and biological properties of soils interact in complex ways to determine their potential fitness or capability for sustained production of healthy, nutritious crops. The integration of growth-enhancing factors that make a soil productive has often been referred to as "soil quality." The Soil Science Society of America (SSSA, 1984) defines soil quality as an inherent attribute of a soil which is inferred from soil characteristics or indirect observations (e.g., compactability, erodibility, and fertility). Thus, soil quality has traditionally focused on, and has been equated with, soil productivity. More recently, the concept of soil quality has been broadened to include attributes of food safety and quality, human and animal health, and environmental quality (Parr et al., 1992). In view of this, soil quality might then be defined as:

> The capacity or capability of a soil to produce safe and nutritious crops in a sustained manner over the long-run, and to enhance human and animal health without impairing the natural resource base or adversely affecting the environment.

Although not well understood, soil quality may also play a major role in plant health and in the nutritional quality of the food that is produced. Thus, if properly characterized, soil quality should serve as a measure or indicator of changes in (a) the soil's capacity to produce optimum levels of safe and nutritious food, and (b) its structural and biological integrity, which can relate to the status of certain degradative processes as well as environmental and biological plant stresses.

Soil quality can decline through all of the degradative processes that are illustrated in Figure 1. Thus, soil quality is directly related to soil degradation which also can be defined as the time/rate of change in soil quality (Parr et al., 1992). The maintenance or restoration of soil quality is highly dependent on organic matter and an array of beneficial microorganisms and microorganisms that it supports. The proper and regular addition of organic amendments such as animal manures and crop residues can effectively offset many of these degradative processes. It is also the best and most expedient means of developing a biologically-active soil that requires less energy for producing crops; increases the resistance of plants to pests and diseases; and enhances the decomposition of toxic substances such as residual pesticides (Sampson, 1981; Hornick and Parr, 1987; Parr et al., 1992).

Soil Quality: The Linkage Between Alternative Agriculture and Sustainable Agriculture

It was mentioned earlier that soil quality is now considered by many in a broader context than just soil productivity, i.e., that the concept should include the attributes of food safety and quality, human and animal health, and environmental quality. It follows then, that the best means of improving and maintaining soil quality are alternative agricultural practices such as crop rotations, recycling of crop residues and animal manures, reduced input of chemical fertilizers and pesticides, and increased use of cover crops and green manure crops, including nitrogen-fixing legumes. All of these help to maintain a high level of soil organic matter that enhances soil tilth, fertility, and productivity while protecting the soil from erosion and nutrient runoff. Effective implementation of these alternative agricultural practices using a holistic or systems approach requires skilled management and innovativeness by the farmer (Papendick and Parr, 1989; Parr et al., 1983,1989).

According to Parr et al. (1992), the attributes of soil quality provide a vital link between the strategy of alternative agriculture and the ultimate goal of sustainable agriculture (Figure 2). Soil quality occupies a pivotal position in this concept. Indeed, many would agree that soil quality is the "key" to agricultural sustainability.

Significant Actions and Events in the Evolution of Sustainable Agriculture in the United State

A number of significant actions have been initiated by the U.S. Congress and the U.S. Department of Agriculture since the late 1970's that have had a profound impact on the evolution of sustainable agriculture. The most important of these are listed in Table 1 and are reviewed here briefly.

Table 1. Significant Events in the Evolution of Sustainable Agriculture in the United States.

Year	Authorization	Action/Event
1978	Food and Agriculture Act of 1977 (i.e., the 1977 Farm Bill)	USDA submits a report to the U.S. Congress on "Improving Soils with Organic Wastes."
1980	Secretary of Agriculture, USDA	USDA submits the "Report and Recommendations on Organic Farming."
1980	Secretary of Agriculture, USDA	USDA appoints first Organic Farming Coordinator.
1982	Secretary of Agriculture, USDA	USDA terminates position of Organic Farming Coordinator.
1983	Non-government action	Institute for Alternative Agriculture is founded.
1984	Secretary of Agriculture, USDA	USDA assigns scientist to conduct cooperative research on organic farming at the Rodale Research Center.
1985	Food Security Act and Agricultural Productivity Act of 1985 (i.e., the 1985 Farm Bill)	U.S. Congress requests USDA to establish research and education programs on alternative agriculture, i.e., low-input/sustainable agriculture (LISA).
1987	U.S. Congress	U.S. Congress appropriates $3.9 million/year to conduct the LISA Program which begins in 1988.
1988	U.S. Congress	U.S. House of Representatives conducts hearings and submits a report on "Low Input Farming Systems: Benefits and Barriers." The intent of the term "low input" is to reduce the use of chemical fertilizers and pesticides in U.S. agriculture.
1989	National Research Council, Board on Agriculture	NRC publishes a report on "Alternative Agriculture" as a follow-up to the 1980 USDA "Report and Recommendations on Organic Farming."
1990	Food, Agriculture, Conservation and Trade Act of 1990 (i.e., the 1990 Farm Bill)	U.S. Congress authorizes USDA to establish a National Composting and Extension Program to facilitate the safe and beneficial use of agricultural and municipal wastes on land.
1990	Food, Agriculture, Conservation and Trade Act of 1990 (i.e., the 1990 Farm Bill)	LISA is now designated as the Sustainable Agriculture Research and Education Program (SARE). Like LISA, the SARE Program helps farmers to reduce or avoid the use of agricultural chemicals. An added dimension of SARE is to strengthen family farms and rural communities.
1990	Organic Foods Production Act of 1990 (i.e., the 1990 Farm Bill)	U.S. Congress authorizes USDA to establish national standards governing the marketing of organically-grown agricultural products.
1993	National Research Council, National Academy of Sciences	NRC/NAS releases a report on "Pesticides in the Diets of Infants and Children" which indicates that these individuals could be at risk from pesticide residues in food.
1993	Secretary of Agriculture, USDA; Administrator, U.S. Environmental Protection Agency; and Commissioner, U.S. Food and Drug Administration	The heads of USDA, USEPA and USFDA pledge their agencies to work with American farmers to reduce pesticide use and promote sustainable agriculture.

USDA Report on Improving Soils with Organic Wastes (USDA, 1978)

Because of intensive cash grain production in monoculture farming systems, soil erosion in the U.S. by the late 1960's and early 1970's had become serious agricultural and environmental problems. This prompted the U.S. Congress in the 1977 Farm Bill (U.S. Congress, 1977) to request that USDA compile a report on "the practicability, desirability, and feasibility of collecting, transporting, and placing of organic wastes on land to improve soil tilth and productivity." This is the first known official request for an inventory of organic waste production in the U.S. Information was requested on the kinds, amounts, and availability of organic materials that could be used as soil conditioners and biofertilizers for improving soil productivity and counteracting excessive soil erosion. A USDA report entitled "Improving Soils with Organic Wastes" was subsequently submitted to the Congress (USDA, 1978).

USDA Report and Recommendations on Organic Farming (USDA, 1980)

In 1979, the Secretary of Agriculture (USDA) appointed a team of scientists to compile a report on organic farming in the United States. The 1980 “Report and Recommendations on Organic Farming” was one of the first official documents that cited serious concerns among farmers, environmentalists, consumers, and the general public about the adverse effects of the U.S. agricultural production system, particularly the intensive monoculture of cash grains (wheat, soybeans and corn) and the often excessive use of chemical fertilizers and pesticides. Among the concerns most often expressed to the USDA Study Team were:

- Increased cost of, and dependence on, external inputs of chemicals and energy,
- Adverse effects of agricultural chemicals on human and animal health, wildlife, and on food safety and quality,
- Decline in soil productivity from excessive soil erosion and nutrient runoff losses,
- Contamination of surface and ground water from fertilizers and pesticides,
- Demise of the family farm and local marketing systems.

The USDA Report found that many farmers, in addressing these concerns, had shifted away from conventional (chemical-intensive) farming systems to a less intensive, low-input or reduced-input approach involving sod-based crop rotations and mixed crop-livestock systems. A major conclusion of the Report was that these reduced-input farming systems are environmentally-sound, energy-conserving, productive, profitable and tend toward long-term sustainability.

Events Following Publication of the USDA Organic Farming Report

The USDA “Report and Recommendations on Organic Farming” had a tremendous impact on agricultural institutions and public policy. Approximately 90,000 copies of the report have been distributed worldwide, and it has been translated into at least five other languages. Nevertheless, there were some temporary setbacks. In 1980, the Secretary of Agriculture appointed USDA’s first organic farming coordinator, but the position was terminated in 1982 by a new administration. The backlash which followed prompted the new Secretary of Agriculture to assign a full-time scientist to the Rodale Research Center to conduct cooperative research on organic farming. A USDA scientist is currently assigned to the Rodale Research Center.

Low-Input/Sustainable Agriculture: LISA (USDA, 1988)

Recommendations of the 1980 USDA Report on Organic Farming provided much of the impetus for the Agricultural Productivity Act passed by the U.S. Congress as part of the Food Security Act, Public Law 99-198, otherwise known as the 1985 Farm Bill (U.S. Congress, 1985). This Act provided USDA with the authority to conduct research and education programs on alternative agriculture, or, more specifically, on low-input or sustainable farming systems (USDA, 1988). The concept that emerged was low-input/sustainable agriculture (LISA) which has contributed to the adoption of soil conservation practices that can enhance soil productivity and a more sustainable agriculture. For fiscal year 1988, Congress appropriated $3.9 million to implement the research and education programs requested in the Agricultural Productivity Act. This funding was increased to $4.5 million for Fiscal Years 1989 and 1990, and $6.7 million currently.

The term “low-input” has been questioned by some who would argue that such systems are not low-input at all, but require considerable inputs of labor and energy. Nevertheless, a U.S. House of Representatives Report (U.S. House of Representatives, 1988) considered low-input or alternative agricultural practices as promising strategies for preventing groundwater pollution and lowering farmer’s production costs. Their report entitled “Low-input Farming Systems: Benefits and Barriers” implied that these goals could be achieved by reducing, or largely excluding, the use of chemical fertilizers and pesticides. Moreover, it is clear from the report that the intent of the term “low-input” is to reduce the use of chemical fertilizers and pesticides in U.S. agriculture.

By virtue of the 1990 Farm Bill (U.S. Congress, 1990), the LISA Program was designated as the Sustainable Agriculture Research and Education Program (SARE). This change was made to account for such added dimensions that would help to strengthen family farms and rural communities.

The Organic Foods Production Act of 1990

A significant action initiated under the Food, Agriculture, Conservation and Trade Act of 1990, i.e., the 1990 Farm Bill (U.S. Congress, 1990), was that Congress authorized USDA to establish national standards governing the marketing of organically-grown agricultural products. While many of the states already have established such standards, this action by the federal government is considered as unprecedented, and a major breakthrough for "organic" farmers.

Recent Initiatives on the Use of Pesticides in U.S. Agriculture

Recently two highly significant events occured with respect to the use of pesticides in U.S. agriculture. The first was the report of the National Research Council on "Pesticides in the Diets of Infants and Children" released in June, 1993, which indicates that these individuals could be at risk from ingestion of pesticide residues in food. The report urges that tolerance levels for regulating permissible concentrations of pesticides in food be based primarily on health considerations rather than on agricultural practices. The second was the joint statement of June 25, 1993, by the Secretary of Agriculture (USDA); the Administrator of the U.S. Environmental Protection Agency (USEPA); and the Commissioner of the U.S. Food and Drug Administration (USFDA) that their agencies were now officially committed to work with U.S. farmers to reduce pesticide use and to promote the principles of sustainable agriculture.

Research Needs and Priorities

The following research should be given high priority by agricultural universities and non-government organizations to facilitate the development of productive, profitable, and sustainable farming systems both in the United States and in other countries:

1. Conduct research on low-input/sustainable farming systems using a holistic approach. Such systems are undoubtedly complex and involve poorly understood chemical, physical and biological interactions. A systems or holistic approach may require the development of new methods and technologies to relate these interactions to organic recycling, nutrient availability, crop protection, energy conservation, and environmental quality.
2. Assess the economic aspects of low-input/sustainable farming systems. This should be done on a whole-farm basis. Such data are absolutely essential because herein is the essence of credibility as to whether low-input/sustainable agricultural systems are economically-viable.
3. Determine the reasons for reduced crop yields during transition from conventional to low-input farming systems. Research is needed to determine the underlying causes of yield reductions so that farmers can make this transition in a shorter time and without experiencing undue risk and economic loss.
4. Conduct on-farm research to obtain more relevant data. Scientists should be involved directly with farmers in conducting on-farm research. In conducting on-farm trials alone, the farmer knows well what happened, but often he does not know why it happened. Research scientists working cooperatively with farmers could play a vital role in making such determinations.
5. Develop new techniques for control of weeds, insects, and plant diseases using nonchemical methods. Pest control methods using parasites, predator insects, and other biological methods to eradicate unwanted species are vitally needed to further the development of low-input, sustainable farming systems.
6. Determine the nutritional quality of crops and the bioavailability of food nutrients for crops grown in low-input farming systems. As cultural and management practices change and as new cultivars are introduced into low-input farming systems, it will be important to monitor changes in nutritional quality. This will assure consumers that dietary standards are being achieved in these low-input systems.
7. Develop more effective methods of technology transfer. One of the best means of transferring technical information is through farmer's organizations and networks. Farmer-to-farmer communication is still the most effective way to extend knowledge and new innovations in the rural community.

8. Conduct periodic surveys or inventories of the kinds, amounts, and availability of agricultural and municipal organic wastes that could be composted and applied safely and beneficially to agricultural land as soil conditioners and biofertilizers.
9. Establish and assign proper nitrogen credits for calculating nitrogen fertilizer rates for crops. Agricultural scientists and extension workers must do more to see that farmers determine nitrogen credits from (a) soil residual nitrate, (b) irrigation water, (c) legumes in rotation, and (d) animal manures, green manures, and other organic amendments in calculating nitrogen fertilizer rates. This would help to prevent excessive use of nitrogen fertilizers that could pollute surface water and groundwater.
10. Identify and quantify reliable indices of soil quality that can be used to predict the effect of management practices on soil productivity and how they relate to the long-term sustainability of farming systems. Determine how soil quality indices can be used to provide an early warning of soil degradation and the need for remedial measures.
11. Identify barriers and constraints that limit the development and adoption of new and innovative methods and technologies for integrating crops and livestock into productive, profitable and sustainable farming systems.

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