PN-ABN-920
ISN 81994

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Sustainable Agricultural Systems
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Ankeny, Iowa

4

SUSTAINABLE AGRICULTURE IN THE UNITED STATES

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The U.S. Department of Agriculture's Report and Recommendations on Organic Farming (USDA, 1980) cited increasing concern among farmers, environmental groups, and the general public about the adverse effects of the U.S. agricultural production system, particularly the intensive monoculture of cash grains and the extensive and often excessive use of agricultural chemicals, both fertilizers and pesticides. Among the concerns most often expressed to the USDA study team were the following:

- Increased cost of, and dependence on, external inputs of chemicals and energy.
- Continued decline in soil productivity from excessive soil erosion and nutrient runoff losses.
- Contamination of surface and groundwater from fertilizers and pesticides.
- Hazards to human and animal health and to food quality and safety from agricultural chemicals.
- Demise of the family farm and localized marketing systems.

Because of these concerns, questions have been increasingly raised in recent years about the long-term sustainability of the U.S. agricultural production system, which has become so dependent on nonrenewable resources and exploitive of the natural resource base.

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 approach based primarily on sod-based rotations and mixed crop-livestock enterprises. A major conclusion

of the report was that these low-input farming systems are environmentally sound, energy-conserving, productive, stable, profitable, and tended toward long-term sustainability.

The Concept of Low-Input/Sustainable Agriculture

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 and technologies. For example, words such as "biological," "ecological," "regenerative," "natural," "biodynamic," "low-input," "low-resource," "agroecological," and "eco-agriculture" are specific terms used by certain spokespersons and groups to refer to various alternative agricultural production technologies and practices that, they feel, are essential to the development of long-term sustainable farming systems. We tend to view the words "organic" and "alternative" as more general terms that appear to embrace a number of the more specific words.

According to Lockeretz (1988), "sustainable agriculture" is a loosely defined term that encompasses a range of strategies for addressing a number of problems that afflict U.S. agriculture and agriculture worldwide. Such problems include loss of soil productivity from excessive erosion and associated plant nutrient losses; surface and groundwater pollution from pesticides, fertilizers, and sediment: impending shortages of nonrenewable resources; and low farm income from depressed commodity prices and high production costs. Furthermore, "sustainable" implies a time dimension and the capacity of a farming system to endure indefinitely (Lockeretz, 1988).

While it is often implied that sustainable agriculture can be attained through the development of long-term, stable, and profitable conservation and production systems, it may be that these systems will have to await the test of time. For example, we may not know whether a particular system has a high, medium, or low level of sustainability for possibly a decade or more. Currently, however, sustainable agriculture has settled in as the ultimate goal. How we achieve this goal will depend upon creative and innovative alternative methods and practices that provide farmers with economically viable and environmentally sound options in their various farming systems.

In 1985, the U.S. Congress passed the Agricultural Productivity Act as part of the Food Security Act, Public Law 99-198 (otherwise known as the 1985 farm bill). This act provided USDA the authority to conduct research and education in alternative agriculture, or, more specifically, on low-input or sustainable farming systems (USDA, 1988). In December 1987, Congress appropriated $3.9 million to implement the research and educa-

tion programs called for in the Agricultural Productivity Act. The concept that has emerged from this effort is one of low-input/sustainable agriculture, or LISA, which addresses multiple objectives, such as increasing agricultural productivity, conserving energy and natural resources, reducing soil erosion and loss of plant nutrients, increasing farm profits, and developing more stable and sustainable conservation and production systems for U.S. agriculture.

At this point it seems appropriate to offer a definition of low-input farming systems that tends to characterize the farmers who were interviewed during compilation of the USDA organic farming report, as well as those low-input/sustainable farmers who are discussed in a following section.

By way of definition, then, low-input farming systems seek to optimize the management and use of internal production inputs (i.e., on-farm resources) in ways that provide acceptable levels of sustainable crop yields and livestock production and that result in economically profitable returns. This approach emphasizes such cultural and management practices as crop rotations, recycling of animal manures, and conservation tillage to control soil erosion and nutrient losses, and to maintain or enhance soil productivity. Low-input farming systems seek to minimize the use of external production inputs (i.e., off-farm resources), such as purchased fertilizers and pesticides, wherever and whenever feasible and practicable, to lower production costs, to avoid pollution of surface and groundwater, to reduce pesticide residues in food, to reduce a farmer's overall risk, and to increase both short- and long-term farm profitability.

Misconceptions About Low-Input/Sustainable Farming Systems

Three misconceptions about low-input/sustainable farming systems commonly arise:

- Low-input/sustainable farming systems represent a return to agriculture that was practiced in the 1930s. This is simply not true. These farmers use modern equipment, certified or hybrid seed, soil and water conservation practices, conservation tillage, and the latest innovations in livestock feeding and handling. They minimize the use, and need for, off-farm purchased inputs of fertilizers and pesticides through sod-based crop rotations, integrated crop/livestock management, and recycling crop residues and animal manures to maintain soil productivity.
- Low-input farming methods result in low output. On the contrary, many of these farmers insist that their crop yields from low-input systems are equal to or even higher than their more conventional neighbors. Studies have shown that crop yields from low-input farming systems might actually

exceed those of conventional cash grain farmers during periods of below average rainfall (USDA, 1980; Lockeretz, 1981). Nevertheless, even if the crop yields from low-input farming systems are lower than from chemical-intensive cash grain production systems, the bottom line is how their yields translate into net returns, which in many cases will be higher with low-input systems.

■ Low-input farmers are really farming at the lower end of the crop response curve. Actually, in many cases the low-input farmer's productivity (i.e., efficiency or output-input ratio) will be high enough to place him or her near the top of the curve. That is, through good management of on-farm resources and crop rotations to provide the necessary levels of plant nutrients and to conserve available soil moisture, he or she may have pushed the crop yield potential up to a maximum level without using any chemical fertilizers or pesticides.

A Study Tour on Sustainable Agriculture

The USDA/U.S. Agency for International Development Project on Dryland Agriculture (USDA/USAID 1987, 1988) held its fourth annual sustainable agriculture study tour, July 10-16, 1988. The participants included some 35 project managers and program directors from the World Bank, USAID, and agencies representing the USDA, including the Agricultural Research Service (ARS), Soil Conservation Service (SCS), Economic Research Service (ERS), Cooperative State Research Service (CSRS), Extension Service (ES), Office of International Cooperation and Development (OICD), and the Institute for Alternative Agriculture (IAA), a nonprofit organization in Greenbelt, Maryland.

The tour visited farms in Kansas, Nebraska, and Iowa where farmers have developed conservation/production systems that minimize the use of external production inputs, such as chemical fertilizers and pesticides. Through innovative management and on-farm research, they have lowered their production costs, reduced their overall risk (even during the severe drought of 1988), and increased their short-term and long-term productivity, profitability, and sustainability. A brief description of the unique features of the conservation and production practices employed by these farmers is noteworthy.

Heiniger Dairy Farm, Fairview, Kansas. There are a number of unique features about the Cory and Shiela Heiniger farm. The Heinigers have demonstrated that with careful planning and innovative management, over a five-year period, they have been able to develop and sustain a 70-cow

4

herd of registered Holsteins on 160 acres of cropland with few purchased inputs; at the same time they have improved soil productivity. Average annual milk production approaches 20,000 pounds per cow, and the farm operation has become a profitable enterprise. The key to success has been computerized feeding and record-keeping, intensive production of a balance of high quality forage, and reducing the need for chemical fertilizers and pesticides. The cows are maintained in a drylot; all forage is chopped and fed directly or stored as silage in plastic bags for use during the nongrowing season. The crop rotation is alfalfa (four to five years)-corn-wheat-sorghum sudan (double-cropped after wheat). The sorghum sudan is sown no-till into wheat stubble after harvest in June and produces a cutting about every 30 days through the summer. In addition to some agrichemicals, off-farm inputs include the purchase of some bromegrass and alfalfa hay.

The crop rotation provides cover for erosion control, helps to break weed and disease cycles, and adds nitrogen to the soil during the alfalfa sequence. Herbicides are now used only on corn; the rate is about one-half of that recommended on adjacent farms that are more intensively row-cropped. In addition, more than 800 tons of manure are produced annually by the dairy herd, all of which is returned to the fields. Recycling of nutrients and organic matter in the manure and a sod-based rotation has enabled the Heinigers to improve soil productivity, fertility, and tilth, thus reducing the need for chemical fertilizers. Their long-range goal is to eliminate the need for purchased fertilizers and pesticides. The Heinigers do not participate in the USDA farm program.

Bender Diversified Crop/Livestock Farm, Weeping Water, Nebraska. Jim Bender operates a farm with 650 acres of cropland and a 90-cow beef herd on moderately hilly land. His ultimate goal is to sell only beef and soybeans. Other crops, including oats, corn, wheat, sorghum, and turnips, are fed to livestock; some crop stubble is grazed. Bender's main approach to achieving sustainability involves implementation of an effective soil and water conservation program, use of sod-based crop rotations, and a reduction in the need for chemical fertilizers and pesticides in the cropping system. Bender acquired his farm in 1975 in "a poor condition" after many years of intensive row-cropping by previous owners who had used high levels of chemical inputs. In his current state of transition back to crop rotations, he has not used herbicides for eight years or chemical fertilizers for two years.

Effective soil and water conservation measures have been achieved by installing 30 miles of jumbo diversion terraces and 25 miles of grassed waterways. In addition, small grains and hay crops have reduced the per-

centage of row crops, which has helped to reduce soil erosion and nutrient runoff losses. The broad terraces allow the use of wide field equipment. His key to successful and economical weed control without chemicals is timeliness of cultivation, which is accomplished almost exclusively with a rotary hoe, tine harrow, and cultivator. These tools have a low power requirement and are most effective when weeds are just emerging or otherwise small. This results in a narrow time frame during which effective mechanical cultivation for weed control can and must be accomplished. However, when conditions are optimum, his 90-horsepower tractor pulling a 36-foot rotary hoe can cover about 30 acres per hour. The entire farm can be cultivated in this manner in less than two days. Bender's costs for weed control are as low as $6 per acre. His main weed problems are two perennials, field bindweed and Canada thistle. He is attempting to use patch tilling to eradicate Canada thistle.

Bender has reduced his capital investment by using and maintaining older farm equipment. His father, who is 80 years old, and one person hired for the summer assist him with the farm work. He uses custom planting of some crops, purchases some hay, and hires custom operators for feed grinding and hay stacking to resolve time-labor constraints.

Bender acknowledges that the cattle operation with calving requires much of his personal attention and considerable time is spent building and mending fences and corrals. From his perspective, however, the key to the success of his farming operation is crop diversification and raising cattle, which enhances nutrient and organic matter recycling. Bender participates in the USDA farm program and grows sweetclover for nitrogen and organic matter return on set-aside acres. But he feels the current farm program is an impediment to his goal of establishing a long-term, sustainable agricultural conservation and production system with primary emphasis on sod-based crop rotations, diversification, and integration of crops and livestock.

Bender's primary motive for choosing this particular method of farming, compared with intensive cash grain production, is to protect the environment and soil resource base. He considers his methods to be a more sound, permanent form of agriculture than conventional cash-grain farming. He says that his yields are higher than his more conventional neighbors in years with below normal rainfall and possibly lower in years with above normal rainfall. Wheat yields on his farm have reached 50 bushels per acre; oat yields were 70 bushels per acre in 1988 (a year of below normal rainfall) and 114 bushels per acre last year with higher rainfall. Bender has been working on a special market certification to qualify as a certified organic producer. To date, however, he has been marketing all of his produce through regular commercial channels.

Akerlund Grain and Livestock Farm, Valley, Nebraska. Delmar Akerlund's 760-acre grain and livestock farm emphasizes low-input methods to reduce operation costs and soil improvement practices to maintain crop productivity. Akerlund estimates that his variable costs of production average about $30 per acre across all crops in his diversified rotation. This compares with $65 to $75 per acre for neighboring farms committed to chemical-intensive corn-soybean production. Akerlund made the transition from chemical-intensive, monoculture-based farming to his present system more than 20 years ago because of concern for pesticide effects on his family's health. It took three years, he said, to make the change and to eliminate the residual phytotoxic effects of pesticides in his soil. No pesticides or commercial fertilizers have been used on his cropland since 1967.

A key factor in improving the productivity of Akerlund's soils is the regular addition of paunch manure, which is imported from a packing plant in Omaha, 30 miles away. He pays only hauling costs, which are nominal. Over the years, the manure application has increased the soil organic matter content from 0.5 percent to more than 6 percent in some fields. The basic crop rotation includes oats underseeded with clover, followed by one or two years of corn, a crop of soybeans, and back to oats and clover. Wheat, rye, and alfalfa are also grown, but mainly to break weed, insect, and disease cycles. Cattle and hogs are produced as an additional source of income, not according to a planned schedule, but rather when Akerlund judges economic conditions to be favorable.

The crop yields obtained by Akerlund without irrigation are equivalent to or somewhat higher than those of his neighbors who irrigate and use conventional farming methods. He produces soybean crops of 60 bushels per acre, 125 to 130 bushels of corn per acre, 60 bushels of wheat per acre, 70 bushels of rye per acre, and 90 bushels of oats per acre.

Labor is not a constraint. Akerlund and a single hired man perform all of the farm operations. He places great emphasis on wildlife preservation and has participated in studies on his farm conducted by the U.S. Fish and Wildlife Service. Results have shown that his farming methods have greatly improved bird habitat and populations on his land. Akerlund does not participate in USDA's farm program because he feels it is of no benefit to him. In fact, he feels it would be a constraint to his low-input/sustainable farming system. He strongly believes that such participation would force him back into the monocultural production of feed grain crops and heavy use of chemicals.

Rosmann Diversified Grain and Livestock Farm, Harlan, Iowa. Ron and Maria Rosmann's approach to sustainability emphasizes ecological

aspects and seeks to achieve a balanced system through crop diversification and animal production. They avoid monoculture or limited-rotation cropping because of the potential for increased erosion and heavy dependence on the use of pesticides, which they feel can lead to a build-up of insects and weeds that are resistant to chemicals. The basic rotation on their 320-acre farm is corn-soybeans-corn-oats-alfalfa. Soybeans are sometimes overseeded to hairy vetch or rye in September before harvest as a winter cover crop for erosion control and green manure. Hairy vetch provides additional nitrogen from biological fixation.

No herbicides have been used on the farm for six years. Better weed control in soybeans is achieved by late planting to enable more opportunity for preplant weed control. Manure from a farrow-to-finish hog operation and a 50-cow beef herd is allowed to compost in windrows before field application in the spring. The Rosmanns have reduced overall nitrogen fertilizer use by 75 percent; on some fields, only 50 pounds of nitrogen per acre are applied to corn.

The Rosmanns feel their way of farming fulfills the concept of sustainability, and they believe it could serve as a model system for the rural community because it accommodates soil and water conservation, environmental protection, and is easily adapted to smaller farms. In their view, sustainable agriculture gets away from large, capital-intensive monoculture farming and promotes the smaller, traditional family-type farm, which has been one of the real strengths of U.S. Agriculture.

The Rosmanns currently participate in the USDA farm program, though reluctantly, because they are young farmers who inherited a relatively small corn base acreage. This base, they feel, must be maintained for now because of federal farm policy and economic uncertainties.

Thompson Grain and Livestock Farm, Boone, Iowa. The 320-acre Richard and Sharon Thompson farm approaches a self-contained ecosystem. Pork and beef are the only produce sold from the farm. All manures and those crop residues not fed to livestock are returned to the soil. In addition, all of the sewage sludge from the city of Boone (population 12,000), approximately 200 dry tons annually, containing about four percent nitrogen, is applied to the fields. No herbicides and only small amounts of fertilizer are used.

Dick and Sharon Thompson began their unique system of farming in 1967 when they experienced problems with residual herbicide phytotoxicity and an increase in hard-to-control weeds, such as foxtail, which they attributed to the excessive use of nitrogen fertilizer.

The basic crop rotation is corn-soybeans-oats-meadow (three years). The

8

corn is a cross between open-pollinated and a hybrid. The crops are fed to a 50-beef cow and 80-sow livestock operation. The livestock manure, along with the sewage sludge, is stored in a large concrete bunker until it can be applied to the fields in early spring before planting.

An innovative feature of the Thompson's farming methods is their development of a ridge-till system for corn and soybeans without use of herbicides. The crops are planted on ridges formed the previous summer, either by a special operation for corn following meadow, or by the last cultivation of corn for the soybeans. Manure is applied uniformly across the fields as early as possible in the spring. The planting operation removes about an inch of soil, weeds, and trash from the ridge peak where seed and starter fertilizer (if used) are placed. The soil, along with manure, crop residues, and any weed seeds, is moved into the interrow or wheel track area. Early cultivation for weed control is performed with a rotary hoe. Later cultivation is done with an implement that mixes the crop residue and manure with soil in the interrow zone and moves the mixture onto the row, thereby rebuilding the ridge. Enough surface residue is maintained to prevent soil erosion and nutrient runoff.

Most soil fertility needs for maximum crop production are met with manure applications and return of crop residue. However, their soils have become somewhat deficient in potassium, and a starter fertilizer containing potassium is often used, especially for soybeans. The starter also provides nutrients for early crop growth before the added organic materials begin to mineralize. The Thompson's ultimate goal is soil improvement so that all fertility needs of their Webster and Clarion soils are supplied through manure and sludge applications.

The Thompsons also conduct extensive on-farm research on tillage practices for weed control, the ridge-till system for soil erosion control, and crop response to different forms of nitrogen. The latter experiments help to monitor how well nitrogen demands are being met with applications of manure and crop residue. The Thompson's do not participate in the USDA farm program.

Thompson is also past-president of the Practical Farmers of Iowa. This organization is an on-farm research and demonstration network of Iowa farmers who are interested in shifting to low-input/sustainable production systems.

Relevant Research on Low-Input/Sustainable Agriculture

The sustainable agriculture study tour visited land grant universities and agricultural experiment stations in Kansas, Nebraska, and Iowa where re-

search relevant to low-input/sustainable farming systems is in progress. Some of this research is briefly highlighted here.

Kansas State University

■ *Herbicide movement affected by tillage.* Studies are underway to determine the potential for movement of two commonly used herbicides, atrazine and alachlor, into shallow groundwater (15-foot water table) as affected by tillage practices and methods of herbicide incorporation into soils. Models will be used to interpret and extrapolate the results. Preliminary results for the field experiment, which is being conducted on a coarse-textured soil, showed no evidence of deep movement of the herbicides.

■ *Nitrogen credits for corn following soybeans.* Studies show that the yield of corn following soybeans averaged 50 bushels per acre more than continuous corn when no nitrogen was applied. The yield difference declined as fertilizer nitrogen applications increased. Similarly, the yield of soybeans following corn was four bushels per acre higher than continuous soybeans. The results show that for each bushel of soybeans produced a pound of nitrogen is supplied to the following corn crop.

■ *Long-term crop rotations and tillage interactions.* Long-term studies were initiated in the mid-1970s to determine the effect of conservation tillage and crop rotations on crop yields and soil fertility/productivity. Rotations of soybeans-wheat and soybeans-grain sorghum under three tillage/residue management systems are being compared with these same crops grown in monoculture. Results show that wheat and soybean yields were higher in rotation with sorghum than in monoculture. Experiments are underway to determine the nitrogen credits that farmers can expect from soybeans for the following grain sorghum crop, as well as effects of tillage and residue management. Another highly relevant study being conducted is to determine the feasibility and practicability of substituting legumes for fallow in the wheat-fallow rotation that is common in the dryland regions of the U.S. Great Plains.

■ *Bioregulation of soil fertility.* Studies are being conducted to determine whether the sequencing of certain crops could effectively enhance nutrient cycling in soils. Particular emphasis is being put on soil phosphorus. The system involves "accumulator plants," some of them deep-rooted, that can use pnosphorus from "pools" that are not readily available to other plants and from well below the usual soil-root zone. The phosphorus used by the accumulator plants then becomes chemically and positionally available for uptake by "user plants," thereby reducing the need for phosphorus fertilizer inputs.

University of Nebraska and Agricultural Research Service

■ *Nitrogen credits for corn from legume cover crops.* Research is being conducted cooperatively by ARS and the University of Nebraska to determine the relative contributions of different nitrogen sources to corn, including soil organic matter, hairy vetch, and nitrogen fertilizers. Additional factors include tillage and crop residues. Hairy vetch has been shown to be sufficiently winter hardy for Nebraska's climate, whereas crimson clover is not. The winter cover crop depleted soil moisture to the extent that germination and emergence of the following corn crop was delayed 12 days during a below normal rainfall year. Thus, winter cover crops may not be practical in low rainfall years in this region.

■ *Long-term crop rotations compared with monoculture corn.* The University of Nebraska initiated a study in 1975 comparing an organic rotation of oats/clover-corn-soybeans-corn with conventional continuous corn. The organic rotation received feedlot manure instead of chemical fertilizers and no pesticides. The continuous corn receives the recommended applications of chemical fertilizers and pesticides. This study has shown that (a) the yield potential of corn in rotation is higher than when grown in monoculture, especially in warmer and drier years; (b) the organic treatments result in increased soil organic matter content, pH, phosphorus, potassium, and soil nitrogen compared to other treatments; and (c) the legume cover crop can use enough moisture in dry years to slow the germination and growth of the following crop.

Iowa State University, Leopold Center for Sustainable Agriculture, and National Soil Tilth Laboratory

■ *Improved management for more efficient use of fertilizer nitrogen.* Research is being conducted on the effect of nitrogen fertilizer rates on crop yields, nitrogen losses, energy consumption, and farmers' net profits. Economic analyses will determine the costs to the farmer of both overfertilization and underfertilization. Results have shown that more than 50 percent of the applied nitrogen fertilizer is lost from Iowa farms through leaching, runoff, and denitrification. Nitrogen fertilizer must be applied in accordance with the crop's nitrogen requirement and expected yield and with proper credit for the available nitrogen already in the system (e.g., residual fertilizer nitrogen). Nitrogen fertilizer should also be applied near the time of greatest demand by the crop so as to minimize losses and maximize nitrogen use efficiency. Methods that show promise include improved soil and plant diagnostic tests and giving proper credits for the contribution of residual fertilizer nitrogen in soil and nitrogen fixed by legumes in crop rotations.

11

■ *Leopold Center for Sustainable Agriculture.* This new institution was established by the Iowa state legislature in 1987 as part of the Iowa Groundwater Protection Act. The mission of this center is to facilitate, coordinate, and support research that promotes the development of low-input, environmentally sound, and sustainable farming systems for U.S. agriculture. The center's research agenda includes such topics as transition to low-input agriculture, nutrient cycling and efficient pesticide use, soil erosion control, soil quality (tilth), ground and surface water quality, preservation and improvement of recreational and wildlife areas, and community stability.

The center will provide research data and technical reports to farmers, policymakers, scientists, regulatory agencies, agriculture-related industries, environmental groups, and the agricultural extension service.

■ *National Soil Tilth Laboratory.* The newly established ARS National Soil Tilth Laboratory on the Iowa State University campus will focus on developing basic knowledge about soil physical, chemical, and biological properties to improve soil structure and enhance soil and water conservation and plant growth. Studies will also be conducted on how management affects soil tilth, with special emphasis on conservation tillage, soil fertility management, and crop rotations. The ultimate goal is to develop management systems that promote good soil tilth for long-term, sustainable farming systems.

The Role and Influence of Public Policy: Some Considerations

Sustainable farming systems in the United States have developed and continue to perform remarkably well, despite a formidable array of specific policy disincentives and broad institutional and structural constraints. On balance, the dominant thrust of U.S. agricultural technology and of trends in farm structure since World War II (e.g., energy and chemical intensiveness, larger farm units, and the specialization and intensification of production practices and enterprises) has created an industrial form of agriculture. These structural changes adversely affect the use of sustainable farming methods, such as those described earlier (Youngberg and Buttel, 1984). Institutional conditions in agriculture, such as low relative energy prices; inflationary land markets; availability of large-scale, capital-intensive farm technologies; favored access of large farm operators to agricultural credit; various features of the tax code; and commodity-based price support policies, have directly influenced farm adaptation strategies in the United States over most of the past five decades. The expansion of farm size and the shift to highly specialized and intensified management practices throughout U.S. agriculture during this period reflect rational farmer

12

responses to these interactive policy and institutional conditions. The oft-repeated admonition to American farmers to "get bigger or get out" simply reinforces a decision-making pattern deeply embedded in modern American agriculture.

Many of these conditions and constraints were noted by the low-input farmers described earlier. However, the most pervasive policy-related theme revolved around the influence of U.S. commodity policy on the adoption of sod-based rotations, a practice widely acknowledged as being of central importance to the development of stable, low-input farming systems (USDA, 1980).

As a general rule, the specific provisions of U.S. commodity policy place farmers, particularly cash grain farmers wishing to include a hay, small grain, or green manure crop in their rotations, at a distinct disadvantage (Anderson, 1985). Consequently, most low-input farmers either forego participation in these programs or participate marginally and sporadically, depending upon individual farm circumstances. There are a number of specific commodity-based program provisions that account for this behavior.

First, U.S. commodity programs tend to encourage chemical-intensive, monocultural cropping systems by focusing program benefits on a handful of crops (Young and Goldstein, 1987). Corn and other feed grains, wheat, cotton, and soybeans receive roughly three-fourths of all U.S. crop subsidies. These same commodities account for approximately two-thirds of U.S. agrichemical use (Fleming, 1987). Most agricultural economists agree that "the selective largess of U.S. commodity programs directs resources away from nonsupported commodities and toward supported commodities" (Young and Goldstein, 1987).

The manner in which program payments are calculated also reinforces farmer decisions to adopt chemical-intensive, monocultural cropping systems. Three factors, crop acreage bases, crop yields, and target prices, determine payments received by farm program participants. We will use corn to illustrate how these factors influence decision-making by individual farmers. However, the same general conditions exist for the other major program crops.

Under current legislation, each farm is assigned a corn base by the county committee of the Agricultural Stabilization and Conservation Service (ASCS). The size of individual farm bases results from the number of acres planted to corn during a designated historical base period. Thus, the more acres planted to corn during the base period (bases are adjusted periodically), the higher the corn base assigned to a given farm.

The second factor used to calculate farm program payments is the average number of bushels produced per acre on a given farm over a stipulated

period of time. Under these arrangements, when subsidy payments are warranted because of low market prices, yields per acre, coupled with the size of the commodity base, bear directly on total payments received by program participants.

Target prices, first introduced in 1973 with passage of the Agriculture and Consumer Protection Act, interact with farm base and crop yield characteristics to determine the total amount of individual farm subsidy payments. Eligible farmers (all producers if no set-asides are required) are guaranteed a per bushel target price. In 1988, for example, the target price for corn was $2.93 per bushel. If average annual market prices over a stipulated period of time fall below the target price, producers receive deficiency payments equal to the difference between the market and target prices. Payment levels are thus tied directly to the size of the crop base on each farm and the number of bushels produced per acre on the base. Total payments are maximized through a combination of large crop bases and high yields per acre.

Taken together, these interrelated program provisions provide powerful, direct incentives for farmers to adopt continuous monocultures (in this case, corn) and to increase their yield per acre. Failure to do so can result in the loss of favorable crop base and yield histories, which can substantially reduce future potential program benefits (Taff and Runge, 1987). From a strictly economic perspective, it is irrational under these conditions for a farmer to introduce long-term, sod-based rotations into his or her cropping system or restrict chemical inputs (i.e., fertilizers and pesticides) on planted acres. Not only do large acreage bases and yield-per-acre crop histories ensure maximum payments under current law, they also add to the value of the farm itself. When farmland is offered for sale, a primary consideration of prospective buyers is the base acreage and established yields of farm program crops. If such bases are currently in effect and acceptably large, the seller can expect a premium price for his land. The common practice of bidding these program characteristics into farm value creates yet another significant economic incentive for adopting high-yield, monocultural, cash-grain production strategies.

The heightened activity in sustainable agricultural research and education programs within the USDA/land grant community is beginning to address the urgent need for reliable and readily available information on low-input farming technologies and systems. Although much work in this area remains to be done, farmer involvement and the emphasis on practical information in these developing programs are particularly relevant and encouraging. Despite these positive trends within the research and education community, it seems clear that future adoption of low-input farming

systems will be severely constrained until appropriate adjustments in commodity and several related policy areas can be implemented.

Research Needs and Priorities

The following research needs should be given high priority by USDA, land grant universities, and nonprofit research organizations to facilitate the development of low-input/sustainable farming systems for U.S. agriculture:

- Conduct research on low-input/sustainable agriculture systems using a holistic approach. Some research that has been conducted by USDA and the land grant universities may be potentially useful to low-input farming systems. Such systems are undoubtedly complex and involve poorly understood chemical, physical, and biological interactions. However, much of the research conducted to date that relates to low-input, sustainable agriculture is piecemeal and fragmentary. A systems or holistic approach, which may require the development of new methods and technologies, is needed to thoroughly investigate and elucidate these interactions and their relationship to organic recycling, nutrient availability, crop protection, energy conservation, and environmental quality.
- 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.
- 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.
- 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 tests, farmers usually go through a sequence of experimentation, assessment, and reevaluation, much of which is based on trial and error. Consequently, the farmer knows what happened, but often he or she does not know why. The research scientist could play a vital role in making this determination.
- 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.

■ 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, for example, the vitamin content and kind and amount of fiber, to ensure consumers that dietary standards are being met.

■ Develop improved methods for technology transfer. One of the most effective means of transferring technical information and practical methodology is through organizations like the Practical Farmers of Iowa. This is a network of farmers who have agreed to conduct on-farm research and demonstrations on low-input farming. They meet regularly at each others farms to share information and compare results. The land grant community should be involved and promote the development of such networks.

■ Assess the economic and farm structure implications of widespread adoption of low-input, sustainable agriculture. Accurate and honest assessments are needed to determine what the impact might be on existing agricultural production and marketing systems from low, medium, or extensive adoption of low-input, sustainable agriculture by U.S. farmers.

■ Develop farm program and policy innovations that are compatible with low-input farming systems. Many farmers would like to shift from conventional to low-input systems. As USDA farm program participants, however, they cannot do so without forfeiting a portion of their feed grain base. In future farm legislation, policymakers must allow a greater degree of flexibility for those farmers who would choose to shift toward low-input, sustainable farming systems.

■ 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. Many Corn Belt farmers still apply heavy applications of nitrogen fertilizer for corn following alfalfa when research has shown that there is already sufficient soil nitrogen available for at least one and probably two consecutive corn crops. This can lead to excess nitrate nitrogen in the soil profile, which is subject to leaching and can cause contamination of groundwater.

The Ultimate Goal

The ultimate goal of many U.S. farmers is to achieve sustainability in agricultural production systems. The primary objectives of these farmers

are to develop farming systems that (a) maintain or improve the natural resource base, (b) protect the environment, (c) ensure profitability, (d) conserve energy, (e) increase productivity, (f) improve food quality and safety, and (g) create a more viable socioeconomic infrastructure for farms and rural communities.

To achieve these objectives, the farmers previously described employ a variety of alternative production and management practices designed to maximize the use of on-farm resources, such as animal manures and legumes, to provide plant nutrients; crop residues, cover crops, and conservation tillage to control soil erosion and runoff; crop rotations to control weeds, insects, and diseases; and energy-conserving tillage systems to save energy and reduce operation costs. By the same token, they seek to minimize their dependence on costly off-farm resources, such as chemical pesticides and fertilizers.

These mixed crop-livestock systems are vital to a sustainable agriculture. It is questionable whether conventional, monocultural feed grain cropping systems or intensive row-crop production can fulfill the objectives and criteria of sustainability because of their necessary heavy chemical inputs, potential for environmental degradation, and excessive energy costs.

Considerable research is now underway at state agricultural experiment stations, including Kansas, Nebraska, and Iowa, that is highly relevant to the development of low-input, sustainable agricultural systems. Additional research needs and priorities are suggested that would contribute significantly to this effort.

The 1985 Food Security Act is not particularly compatible with, or conducive to, alternative agricultural practices or the development of low-input, sustainable farming systems. Certain aspects of current public agricultural policy contribute to conventional production practices and pose barriers to the wider scale adoption of more sustainable practices and systems. For example, oats and legumes, such as alfalfa, vetch, and sweet clover, are essential for establishing low-input crop rotations. Under current policy, however, planting these crops means that farmers would necessarily forfeit a portion of their feed grain base. Most of them are not willing to do this because of economic considerations and uncertainties about future farm policy legislation. Hopefully, policymakers in future farm legislation will provide a greater degree of flexibility and accommodation for the development of low-input, sustainable agriculture systems for U.S. farmers.

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18