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Journal of Soil & Water

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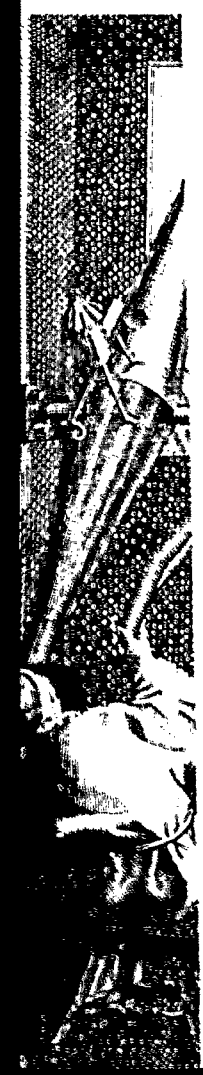

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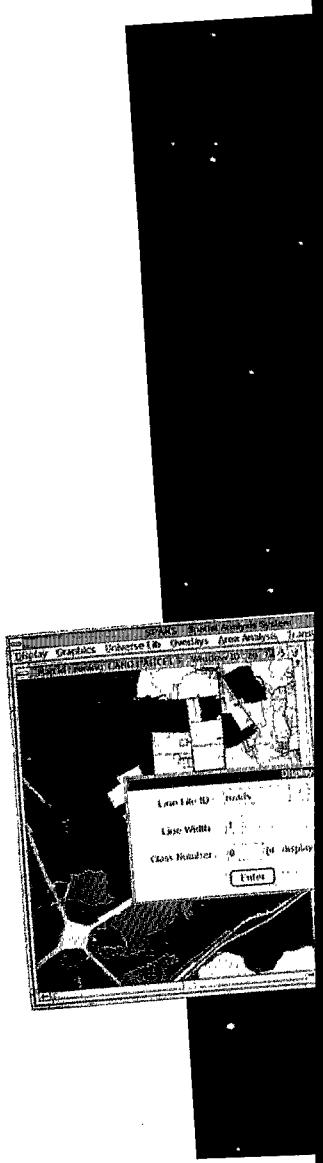

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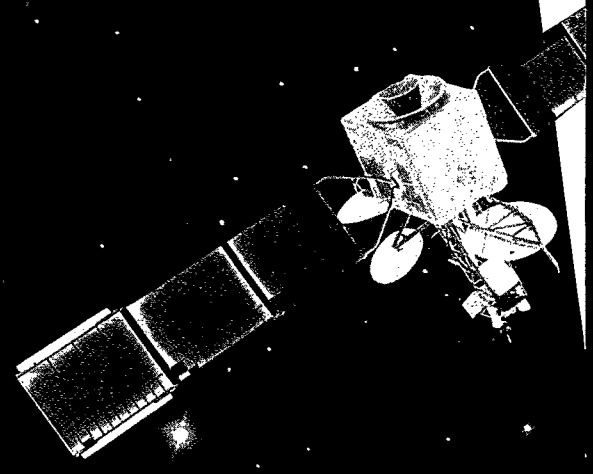

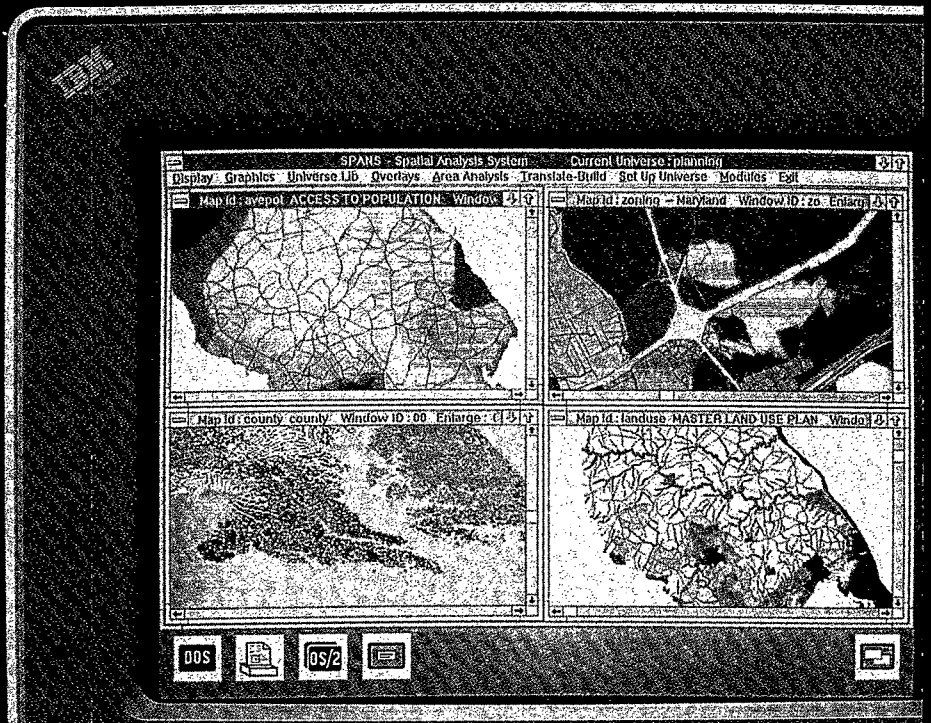

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Cover: Agricultural engineer James L. Butler of Tifton, Georgia, examines corn planted in a Tifton 44 bermudagrass sod. Agricultural Research Service photo by Rob Flynn.

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SOIL AND WATER CONSERVATION SOCIETY

THE SWCS VIEW

Sustainability's promise

SUSTAINABILITY is a buzzword these days. We talk of sustainable forests, sustainable soils, sustainable agriculture, sustainable development—sustainable this and that. In reality, sustainability is not a new concept. Conservation pioneers from George Perkins Marsh to Gifford Pinchot and Aldo Leopold alluded to the concept in their writings, as did the founders of SWCS when they wrote in our mission statement that we would exist "to emphasize the interdependence of natural resources and thereby to educate people so they can use and enjoy these resources forever."

But sustainability remains a buzzword. The question is how constructive a buzzword it proves to be.

Much time and effort has been spent in the agricultural conservation community over the past two or three years arguing about semantics. Which term better describes the concept of sustainability in an agricultural context? Is it simply "sustainable," or "low-input," or "low-input sustainable"? Or perhaps "alternative," or "regenerative," even "organic"?

SWCS contributed to this semantic wrangling a year ago in planning its national conference, "The Promise of Low-Input Agriculture: A Search for Sustainability and Profitability," that was held in Omaha, Nebraska. Note that we even tried to cover what we thought were all of the important semantical bases in the conference theme.

Far more important, however, was and is the articulation of the concept of sustainable agriculture *as a way of thinking*, which it is, and promoting the many techniques encompassed by this way of thinking.

At last fall's Agricultural Outlook Conference in Washington, D.C., John Ikerd defined "sustainable agriculture" as those farming systems that are capable of maintaining their productivity and usefulness to society indefinitely. Such systems, he said, must be resource-conserving, socially supportive, commercially competitive, and environmentally sound.

Many speakers stress that there is no conflict between ecological sustainability and economic sustainability, not in the long run or even the short run, from "society's point of view." The only potential conflict exists between individual farmers and society in the short run.

The logical difficulty with accepting this statement is that farmers are also "part of society." Another point to remember is that a shift from existing agricultural systems to new ones is not risk-free.

In the United States, the consumer has come to expect food that is plentiful, nutritious, and free from contaminants and/or other ingredients that may cause short- or long-duration health hazards (including various forms of food poisoning, etc.).

Agricultural systems that are profitable for individual farmers may or may not be sustainable. Similarly, individual sustainable farming systems may not be profitable in the short run.

This being the case, one would assume that the adoption of more sustainable production systems would require considerable in-depth thought and research. There are, however, some major considerations. First, some of the existing crop, pasture, range, and forestry operations are already on a sustainability path. Second, the sheer size, magnitude, and complexity of today's food production systems require consideration, lest the proposed cures be worse than the presumed disease. Third, federal farm policy gradually continues to be modified to encourage flexibility and experimentation with both agronomic practices and alternative crops.

We might refer to the adoption of these approaches to sustainability as the mainstreaming of these practices in conventional agriculture, and it is to this end that the SWCS conference in Omaha a year ago and this issue of the *JSWC* is dedicated. For the adoption of crop rotation, integrated pest management, and the other components of sustainable agricultural systems, however incremental, holds the promise of improved soil erosion control, better waste quality protection, enhanced wildlife habitat, and a more acceptable quality of life generally for producers and consumers alike, not to mention its positive, long-run consequence for such an important matter as the continuation of life itself on this earth.

Richard Duesterhaus, President

SOIL AND WATER CONSERVATION SOCIETY

The Soil and Water Conservation Society is a multidisciplinary organization dedicated to promoting the science and art of good land and water use worldwide, with emphasis on the conservation of soil, water, and related natural resources, including all forms of beneficial plant and animal life. To this end, SWCS seeks through the *Journal of Soil and Water Conservation* and other programs to emphasize the interdependence of natural resources and thereby to educate people so that they can use and enjoy these resources forever.

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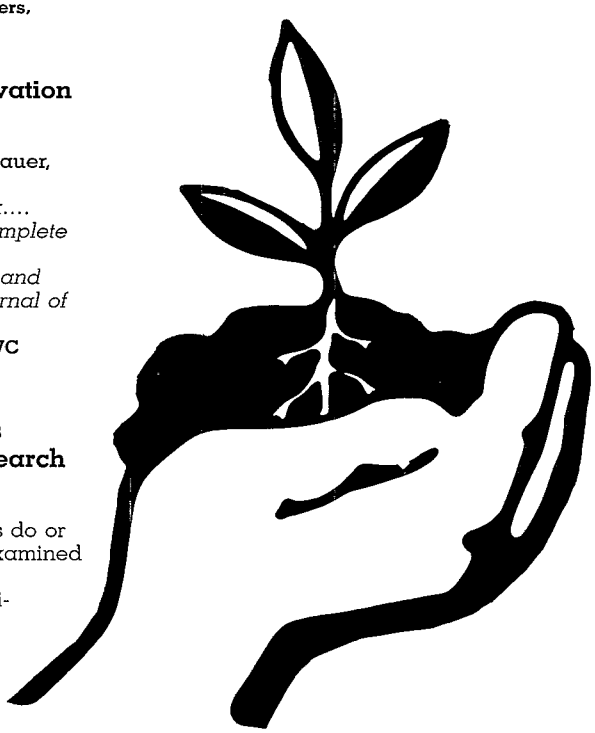

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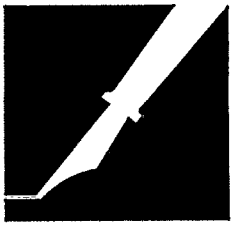

PEN POINTS

Privileges, not rights

Jim Jacobs' article on the unexpected consequences of the Food Security Act [*JSWC*, September-October 1989, pp. 456-457] brought up some very good points. However, while I agree with most of the points, there is one that I cannot accept.

He says that the Food Security Act has an utter disregard for "individual rights." What rights are being disregarded? The public has not decided "that a wetland owned by an individual should not be disturbed," only that if they do disturb that wetland that certain government monies will no longer be available to them.

Farmers do not have an inherent "right" to cost-share and price supports, any more than the average wage-earner has an inherent "right" to their salary regardless of how they do their job. In every aspect of life, Americans have become enamored with declaring their "rights." Most of those rights do not exist. There are privileges that we must earn, but few rights. Let's stop talking about our rights, and think a little more about our duties.

Annora Equall
Havre, Montana

On chemical dependence

American agriculture, like our society, is chemically dependent. The removal of chemical pesticides and synthetic fertilizers from food production would cause the whole system to crumble. Our dependence is nearly total. Though it's considered impolite to point out the chemical dependence of friends or family to booze or pills, addiction means the same thing whether it's applied to a drug user, our soils, or society.

We have misused our soils, mining our fertility, compacting structure, gassing microbes, and allowing tons to wash away from our hillside fields. This once great resource, intended to last for generations, is becoming exhausted. Thoughtlessly, we have taken too much out and put little back. By whatever measure, our once great land is disappearing into streams and suburbs—sick and sterilized. Because the goal has been production at any cost, we continue to pour on expensive fertilizers to mask the soil's loss of natural fertility. The quality of the crop, its nutritional value to man and animal, is actually decreasing.

Against competitive insects, fungi, and weeds, we use poisons. Our dependence on pesticides means we've neglected other crucial biological and ecological practices. Instead of breeding varieties resistant to pests, we've chosen to breed varieties resistant to pesticides. When pests, insects, or weeds become resistant to pesticides, which is easy for them with their large populations and breeding capacity, we find another, more toxic material. Instead of working with our farms and the natural orders of diversity and sustainability, we find ourselves at war with Nature. Instead of following natural rotations in the field, we plant the same crop year after year, creating perfect opportunities for increasing levels of pests. We've created a system that depends on chemicals: they enter our environment and they enter us.

I don't know a farmer who enjoys using chemicals, but faced with a mortgage payment and a crop-threatening pest, the choice is inescapable, and you spray. Farmers dance to several tunes, none of them their own. Consumers demand cosmetic perfection. Grocers demand constant supply and longer shelf-life. Processors demand undamaged crops. Bankers demand payment on time. Farmers have difficulties with these contradictory demands. Agricultural chemicals satisfy some of these demands, but evidence seems clear that they don't yield safer, healthier food. Farmers know this: They're not being paid enough to produce safe, healthy, life-sustaining food, nor to be good stewards of the Earth. Society asks them to do this for free, for altruistic reasons. Farmers know they can't stay in business by resting their land, rotating for pest control, and plowing down green manures to build soil structure and fertility. Only production will keep them in business, and the sheer demands of production are destroying our land and our farmers; they're locked into a system of chemical and economic dependence from which they find no escape.

Federal farm policies support inadequate and destructive agricultural practices and have created a gigantic farm welfare system.

Ecological and regenerative solutions are hard to come by when decisions are made solely on the basis of production per acre. We must ask ourselves, what is the real cost of putting a meal on America's table? The present system has succeeded in making our food the cheapest in the world for consumers, but at what cost to farmers, their communities, and land?

The time has come for Americans to realize that the bottom line of our cheap food system isn't on the supermarket tape. We need to factor in the decline of soil fertility, erosion and related problems, food safety, polluted groundwater, the health troubles of farmers and farm workers, tax money used in commodity payments, and the destruction of our family farms and rural communities.

As with other forms of chemical dependence, the first requirement for a cure is acknowledgement of our denial of the problem. After acknowledgement comes withdrawal. During withdrawal, the farmer will adjust philosophically while the fields adjust biologically. Emotional and economic support will be needed for three to five years. Help will also be needed from research institutions, cooperative extension personnel, mortgage holders, and consumers. Agriculture stands with a number of major social and environmental issues, such as waste disposal, energy production and use, global warming, and critical resource exhaustion. It demands our attention, and it's right on our dinner plate!

David Stern
Rose Valley Farm
Rose, New York

On farming sustainability

"The Search for Sustainable Agroecosystems," [*JSWC*, March-April 1989, page 111] is a meaty article; I underlined about every sentence and further bracketed paragraphs for emphasis.

Yet the article focused on crops...not

one word about livestock as part of integrated, low-input, sustainable agriculture. This may add complexity, but it is my feeling that forage-grain (cash crop)-livestock diversified individual farm units, especially in the corn, bean, and wheat regions, offer the ultimate opportunity for sustainable, highly profitable, low-input agriculture.

Forage-grain-livestock setups were the norm prior to the launching of "property line to property line industrialized agriculture," abetted by a secretary of agriculture who advocated planting "fencerow to fencerow." The fences have disappeared in favor of tilling every last square inch.

What is needed for a completely integrated and meaningful agricultural ecosystem is the inclusion of legumes and livestock in the farm setup.

Now, of course, the reaction of triple-A farmers to such a notion is that pasturing is inefficient and who wants to invest in fencing and fuss with livestock? I have seen the statement that farmers are reaching the crossing lines on the P&L charts where it will not be profitable to raise corn, beans, or wheat in spite of "industrial efficiency." Beef operations are marginal, in spite of larger and larger feedlots.

Forage-grain-livestock setups offer the only complete scenario for profitable, sustainable agriculture. Once it is examined, it will be seen that it is also the lowest input method, simply by the nature of its practices.

So, what has come along to make this diversification so wonderful? Two things: rotational pasturing and the machine to make it viable.

Rotational pasturing is everything from simply dividing the range in twain to rapid rotation, high-density pasturing. The crux of its management is appropriate rest periods for a pasture after "clipping" it by intense pasturing in early stages of maturity when the total digestible nutrient and protein levels are the highest. There are many nuances in the management of such a setup, but they will fall into place.

What is the machine? The solution is quick and easy mobile fencing! (I have developed a machine that installs and removes fence 40 to 80 rods an hour, depending on complexity. It uses conventional T-posts, barbed or smooth wire and fasteners. It runs off the hydraulics of a 35- to 40-HP tractor.)

Up to this point rotational pasturing has been hampered by the labor intensity of the system. Mechanizing it will fling wide the gates to getting the most out of pasture and crop rotations.

Truly quick and easy mobile fencing will enable farm managers to take ultimate advantage of all the benefits of nature in an integrated farm system, plus it will slash production costs as well as save soil and water and stop pollution. Including livestock will complete the normal natural soil-plant-animal biological cycle and will allow the farmer to add value to his crops that he himself will furnish at cost—not retail or even wholesale, but at cost!

I am not advocating a complete move to grass and livestock—rather a move into a well-balanced and integrated forage-cash crop-livestock setup. Being diversified gives an operator a three- or four-legged stool to sit on. Having the facility to increase or decrease one or the other or all modalities 5 to 10 percent without upsetting the apple cart gives him the opportunity to adjust midstream to weather, crop, and market conditions.

The fencer will be the management tool of the next evolution in the next generation, which will start when a farmer can see profits increased $100 to $300 per acre without a huge investment or major alteration of his present setup. The fencer will allow him to move into diversification stepwise and gradually rather than going whole hog into beef, grains, swine, sheep, horses, or what have you.

I also envision a network of farm management modules with field men in soils, agronomy, animal husbandry, engineering, and finance working as a team with the farmer who makes the final decisions to match his likes, dislikes, resources, and talents. The network will furnish information from the experience of others and the stacks in extension services, plus up-to-date information on weather, crop, and market conditions—the three biggest gambles in farming.

There is a real possibility of a new and brighter day when the farmer and rancher will have more control over his own destinies and operations. Then life will be more challenging, interesting, profitable, and fun!

Robert S. Hulburt
Chicago, Illinois

Best *JSWC* yet

The September-October *JSWC* just came and is the best journal of all time. It covers sustainable agriculture, water quality, the new farm bill achievements, the district and SCS delivery system for services, etc. It is outstanding and every author and contributor merits a heartfelt thanks!

Larry Summers
Columbus, Ohio

New Mexico study classified

I wanted to point out an inaccuracy in the November-December *JSWC*. The New Mexico State University study referred to in the "In the News" section (page 588) was misinterpreted. The statement that the study "says that there is no justification for the private harvesting by ranch owners of public game animals and wildlife" is inaccurate. The study reported, "We find no compelling reason for the New Mexico legislature to change the law so as to encourage the commercial harvest of free roaming native wildlife for purposes of meat production." The news story also stated the study reported "that landowners should pay user fees as do other hunters." I could find no place in our study that user fees were even mentioned and we certainly made no recommendation similar to what was stated.

New Mexico State University is on the forefront of assisting landowners in the implementation of wildlife enterprises that are biologically, legally, socially, and economically sound. Our goal is to convince landowners that wildlife on their land is an asset not a liability. We feel that as more landowners receive incentive to manage for the improvement of habitat and populations beneficiaries will be the landowner; the public; and, most importantly, the wildlife.

James E. Knight
New Mexico State University

> *Farm organizations, the agricultural committees of Congress, the U.S. Department of Agriculture, and the land grant colleges have lost control of the farm policy agenda.*

VIEWPOINT

The changing policy environment for the 1990 farm bill

MANY years ago, farming was different than other occupations. It was more a way of life than a business. Farmers were self-sufficient. They bought and sold little. They took to market only what was in excess of their family needs. Despite regional differences, there was a generally recognizable rural culture, tradition, and lifestyle. Farmers were readily distinguishable from other people by speech, dress, and manner.

Farmers were considered unique, and worthily so. They were given preference in the legislative forum. For example, because farmers were special, they were given preferred access to land and water. When general social legislation was enacted, we often excluded agriculture because of its uniqueness. Consider some of the major exclusions sought by and granted to agriculture:

- Exemption from a whole set of laws related to hired labor: child labor, working conditions, minimum wages, workmen's compensation, collective-bargaining rights, unemployment insurance.
- Preference with respect to determining rates for transportation of farm products.
- Exemption from laws regarding the restraint of trade granted to farm cooperatives.

These exclusions have now come under fire. Agriculture is being challenged on all of them, including price and income supports available to farmers, but not to automobile manufacturers or hardware merchants.

Agriculture today is being deprived of its preferred position, including its special claim on natural resources. Ecological questions are placed on the national agenda by environmentalists. Land and water questions are raised by those who oppose the long-held idea that farmers have first claim to the use of these resources.

The conclusion is inescapable: farm organizations, the agricultural committees of Congress, the U.S. Department of Agriculture, and the land grant colleges have lost control of the farm policy agenda.

When we snap on the television set to watch a football game, the first question we ask is, "Who's got the ball?" The agricultural establishment had the ball in the farm policy arena for 100 years or more. But sometime during the 1970s and 1980s there was a turnover—a turnover so gradual that the public and even the principals have not yet fully recognized it. Nonetheless, the initiative has changed hands.

From what kind of power base can farmers deal with this situation? Their major asset is goodwill. Repeated surveys have shown that public opinion is favorably disposed toward farmers. The historic position favoring agriculture continues but dwindles.

Whatever the political power base may be, we must in the years ahead work out the assimilation of agriculture into the mainstream of American life. As I see it, this is likely to be the major factor affecting farm and food policy during the debate on the 1990 farm bill. American agriculture is now part of an interdependent world.

The environment is likely to be the most contentious sector in the 1990 farm bill. Agreed-upon facts are few, and opinions are strongly held. Quantification of environmental degradation and the dangers of unwholesome food is extremely difficult, and effective ways to cope with these dangers are at least as difficult. But the public perception will govern. The objective facts, whatever they may be, are likely to be overwhelmed.

The public has greater interest in an incremental improvement in environmental practices than it has fear of a marginal increase in the price of food. The old farm argument that environmental actions are likely to increase the cost of food will not be persuasive.

The time is past when a farmer could feel sole responsibility for management of the resources to which he held title. Farmers are now a minority. With what strategy should they enter the forthcoming debate on farm and food policy?

De-escalation, common ground, and tradeoffs are the ingredients of good public policy. Each has its potential contribution to the development of sound farm and food policy during the years ahead.

Issues might be de-escalated, for example, by searching out available facts about food safety and environmental threats and supporting leaders who respect the facts.

Areas of common ground could be found if sought out. Farmers and nonfarmers are interested in each other's well-being. As nonfarm people prosper, farmers have a better market for their products. If farmers are sufficiently rewarded, they will provide a bountiful supply of wholesome food.

Tradeoffs might be worked out. Better resource use, a concession to the environmentalists, could help farmers pass legislation to reduce gyrations in farm income.

For a hundred years farmers had the policy initiative. They called the signals, moved the ball, and put points on the scoreboard. But sometime during the past 15 years or so, there was a turnover. Like it or not, farmers must now play defense. There is in this game one thing worse than losing the ball: that is to lose the ball and think you still have it.

Don Paarlberg

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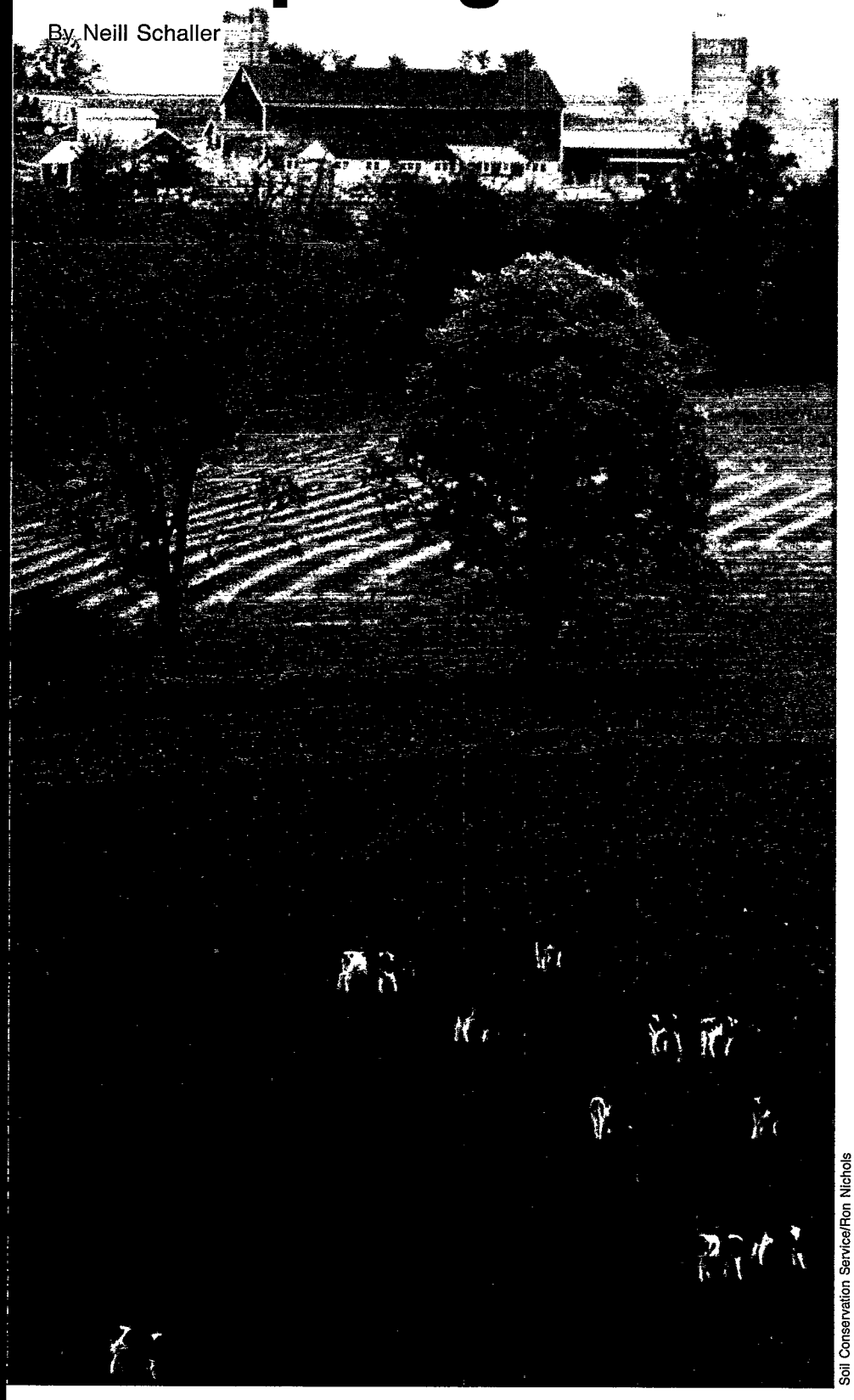
Mainstreaming low-input agriculture

By Neill Schaller



Soil Conservation Service/Ron Nichols

PEOPLE hear terms like low-input, reduced-input, sustainable, organic, biological, regenerative, and alternative agriculture. They wonder if these are all the same thing. They don't know what path the search for sustainability should take, and how they will know when they get there. Many look in vain for a single definition to guide them.

Meanwhile, farmers are trying different approaches, unworried about how to define them. Several who described their farming operations at a U.S. Department of Agriculture (USDA) hosted conference on low-input agriculture ended their remarks by saying, "I don't know if what I'm doing is low-input sustainable agriculture or not."

There are reasons why we lack a single, agreed-upon definition of what the search is all about. First, low-input sustainable agriculture is a way of thinking or a philosophy. It is not a farming practice or a method—which is usually easier to define. In fact, to try to force a specific definition of low-input, sustainable agriculture would be a mistake because it is a way of thinking.

Second, low-input sustainable agriculture has evolved mainly as a reaction to the adverse environmental and, more recently, economic side effects of conventional agriculture. It constitutes a criticism of capital-intensive, chemical-intensive monocultures. Low-input sustainable farming could be defined solely in terms of what it is a reaction to; but then how do you define conventional agriculture?

Means versus ends

One way to minimize possible confusion about the search for a sustainable and profitable agriculture is to think about it in terms of means and ends. The ends are where we want to go—call them goals or the purpose of the search, if you prefer. The means are ways of getting there—the practices and specific methods of farming.

Realistically, we should visualize a continuum of means and ends. Some means can and should be thought of as intermediate ends, as well as means. You get a job (a means) to earn money (another means, or an intermediate end) to buy material things and services (also a means or an intermediate end) that enhance your well-being (a higher end).

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Different people may see the means and ends of the same activity quite differently. Take the means and ends of farming itself. Some say you farm to live, others that you live to farm. Money, a means for most people, seems like an end in itself to others.

Let's try out the means-ends test on some existing definitions. The 1980 USDA *Report and Recommendations on Organic Farming* includes a definition that is still cited as a useful description of sustainable as well as organic farming. It defines the latter as "...a production system which avoids or largely excludes the use of synthetically compounded fertilizers, pesticides, growth regulators, and livestock feed additives. To the maximum extent feasible, organic farming systems rely upon crop rotations, crop residues, animal manures, legumes, green manures, off-farm organic wastes, mechanical cultivation, mineral-bearing rocks, and aspects of biological pest control to maintain soil productivity and tilth, to supply plant nutrients, and to control insects, weeds, and other pests" (*10*).

A more recent definition of sustainability is found in the legislation establishing the Leopold Center for Sustainable Agriculture at Iowa State University. It says that sustainability is "...the appropriate use of crop and livestock systems and agricultural inputs supporting those activities which maintain economic and social viability while preserving the high productivity and quality of Iowa's land" (*4*).

Finally, the American Society of Agronomy recently formulated this definition: "Sustainable agriculture is one that, over the long-term, enhances environmental quality and the resource base on which agriculture depends, provides for basic human food and fiber needs, is economically viable, and enhances the quality of life for farmers and society as a whole" (2).

Note the similarities and differences among these definitions. Some talk almost entirely about means, while others identify a mixture of ends and means.

Because different people see the ends and means through different eyes, we can understand why confusion may arise. Consider the term "low-input sustainable agriculture." Though popular in Congress and elsewhere, the name can cause problems. The implied end is a sustainable agriculture, but what is low-input? I see it as a means to that end (a means, by the way, that may not be appropriate for all farms in every region). But not everyone thinks that way. Indeed, some assume that proponents of low-input, sustainable agriculture consider low-input farming, specifically low-chemical-input farming, as an end in itself. Behind that assumption lies the unfortunate belief that low-input, sustainable agriculture is just a new name for the organic, antichemical movement of some years ago.

Sustainability and/or profitability?

Are we talking about separate ends or just one end? Ideally, we are talking about a single end, agricultural sustainability, which includes profitability along with other equally important criteria. It is a marriage of ends, not unlike the one Bob Rodale challenged the Soil and Water Conservation Society to help bring about four years ago (*6*). He was talking then about a marriage of conservation and production agriculture. The problem, he said, was that conventional agriculture treated efficiency, production, and profit as the primary ends and conservation as an add-on consideration. A marriage was needed to give those ends equal billing.

Whether the union of conservation and production agriculture succeeded or failed is an interesting question. The Conservation Title of the 1985 Food Security Act could be cited as evidence of success. But now I think we are talking about an even bolder union—a marriage of agricultural productivity and profitability, resource conservation and environmental protection, and the enhancement of health and safety.

The sustainability of agriculture, I should add, may not be the ultimate or highest end on the means-ends ladder. For instance, it can be thought of as a means to the sustainability of society as a whole and the well-being of all people. Sustainability is definitely an intermediate end to Bob Rodale, who has given years of thought to the meaning of these words. Speaking at a national conference on "Natural Resources for the 21st Century" last year, he expressed the hope that one day we will move beyond sustainability to a still higher end, which he calls regenerative agriculture (*7*).

Means to sustainable agriculture

Most discussions about the sustainability of agriculture seem to concentrate on the means to that end. We are more comfortable talking about them than about ends. In fact, many professionals are taught early that to ensure their objectivity they should stick to lower rungs on the means-ends ladder. There they can safely judge the goodness or badness of alternative means on purely technical grounds—how effective the means are for achieving specified ends.

Relationships between different means to sustainability can take several forms. They can complement or supplement each other, for example, when crop rotations, conservation practices, and reduced use of insecticides all pull in the same direction. Means also can be in conflict. When conservation tillage requires more herbicides, it conflicts with the means of lower dependence on purchased chemical inputs. Not all such conflicts can be avoided, but knowing when different means could conflict can help us choose those that are least likely to work at cross-purposes.

Conservation and LISA

The conservation community has played a lead role in shaping sustainable agriculture as a way of thinking. Conservation groups have been instrumental in persuading Congress to authorize and fund USDA's Low-Input/Sustainable Agriculture (LISA) research and education program, now in its third year.

This should come as no surprise. The ties between conservation and other dimensions of sustainable agriculture are fundamental:

- Conservationists are quite familiar with the adverse impacts of conventional agriculture on natural resources and the environment.
- The idea of conservation, like that of low-input agriculture, implies that farming is a partnership with nature. The mindset that sees nature as something to be conquered simply is incompatible with sustainability.
- Conservationists, like others searching for sustainability, do not equate it with preservation of resources. But they certainly understand the difference between renewable and nonrenewable resources.
- Conservationists know that self-interest, pursued to the extreme, does not benefit society, as Adam Smith implied that it might two centuries ago.

This perspective is evident throughout the history of the conservation movement. As one writer has put it, "Behind legislation like the Soil Erosion Act was a national groping for a new social and environment ethic. In the place of the old emphasis on private good, the new ethic began with defining the collective good; and the good not only of those now living but of those to come. The program of soil conservation initiated in 1935...was expected to be one of the clearest expressions of this social ethic. Henceforth, each generation was to leave the earth in as good shape as it had found it, or in even better shape..." (*9*).

The traditional ends and means of conservation and those of agricultural sustainability may not always be in harmony, for example, increased use of herbicides accompanying conservation tillage can conflict with the idea of reducing purchased chemical

inputs. Looked at from the other direction, conservationists might wonder if low-input practices, such as minimizing the use of purchased chemicals, could run counter to efforts to curb soil erosion. Another conflict between conservation and other dimensions of sustainability could arise if conservation reserve programs have the effect of restricting the acreage a farmer could otherwise include in a farm-wide rotation scheme.

Conservationists themselves may be uncomfortable with low-input, sustainable agriculture for a number of reasons. Some may simply think that their long struggle to protect soil and water has suddenly become only a part of a much bigger idea now championed by people outside the conservation field. Others may be uneasy about the new search for sustainability because they are just not sure who is in it and why.

This skeptism, if it can be called that, is suggested in a recent editorial by a conservation leader who wrote: "The potential for good management of soil and water resources under low-input agricultural systems is bright but not automatic. Soil and water conservationists must keep a keen eye on the development and popularity of low-input agriculture to ensure that these basic resources, so essential for food production, are not degradated by new farming systems" (*8*).

Moreover, sustainable agriculture could come across to some conservationists as an embarrassing indictment of the people and organizations of conventional agriculture, the agriculture most conservationists have grown up and worked with all their lives. The benefits of that association to conservationists apparently have more than overshadowed any ill feelings on their part because conservation traditionally has played second fiddle to agricultural production.

People in fields other than conservation who are joining the search for a sustainable agriculture could be apprehensive about the conservation connection, too. They may believe that conservationists have been far too willing to let production agriculture be king-of-the-mountain and to be satisfied with the role of placing bandaids on injuries to land and water caused by conventional farming.

These views and feelings are natural and, I trust, a minor source of friction. But even then they should not be left unattended. All participants in the search for a sustainable agriculture need to understand and respect each other's perspectives. Strange bedfellows or not, they need each other.

The matter of mainstreaming

Four conditions in particular will surely influence the extent to which low-input, sustainable farming will be adopted:

Soil Conservation Service/Lynn Betts

The ties between conservation and other dimensions of sustainable agriculture are fundamental.

► The availability to farmers and others of reliable facts and information about low-input farming.

► The removal of policy and other institutional barriers to farmers' adoption of low-input practices.

► The availability of financial or other incentives to encourage adoption.

► Regulations affecting the availability and use of production inputs and farmers' choice of practices.

Facts and information. For several years, farmers have been doing much of their own low-input research, disseminating it to other farmers directly or through private organizations. The USDA-land grant research and extension system has only just begun to respond in a concerted way to farmers' needs for information on low-input options. The new USDA LISA program is giving that need important visibility and support. But the LISA program eventually must become mainstream research and extension if the nation's farmers are to have adequate access to the facts and information they need.

Right now, the response of the traditional research and extension system to LISA is mixed. The new program is gaining attention among research and extension staff, but there are persistent signs of uneasiness with it. For example, all researchers do not endorse the program's feature of involving farmers directly in the selection and conduct of LISA projects. Although they agree that farmer inputs to research are critical, some doubt the ability of nonscientists to play a bigger role than that in the research process.

Farmers are not the only people who need more and better information about low-input, sustainable agriculture. Policy analysts and policymakers, along with interested publics, must have reliable information to make informed judgments about it. This crucial need is barely recognized today. A mixture of myths and realities now surrounds the subject.

Some people, including many economists, believe that low-input farming is inherently unprofitable and, therefore, will never be mainstream agriculture. Others disagree completely. They add that the profitability of low-input farming cannot be compared with that of conventional agriculture using only conventional economic yardsticks. Even if it were less profitable in dollars and cents, low-input farming would come out ahead of conventional farming when adding in its nonmonetary benefits to the farmer and to society.

Others see low-input agriculture as going back to the way our grandparents farmed—using labor instead of capital and raising livestock to supply manure and to harvest forage grown on the farm. As this reasoning goes, widespread adoption of low-input farming would require an enormous increase in the nation's livestock population. Even if that were attainable, it would cause a terrible problem of animal pollution, depress market prices for livestock, and reduce total

agricultural production, thereby threatening food shortages.

The counter argument is that low-input farming is anything but a step backward, that it incorporates many modern, sophisticated, high-yielding practices, such as biological pest control, for one. And fears of being overrun by livestock are grossly overstated. Profitable low-input farming is quite possible without any livestock at all on many farms.

Another issue some raise is how many farmers actually will be willing and able to devote the additional management time and skills that low-input agriculture is apt to require. Clearly, we need facts and information to intelligently sort out this and other myths and issues. That means research and education, much of it by economists and other social scientists. So far, too few economists in particular have responded to this need, perhaps because they do not see low-input farming as a profitable and therefore viable option.

Removal of barriers. Farmers often single out commodity price and income support programs for crops, such as feed grains, wheat, and cotton, as penalizing those who shift to low-input sustainable practices. The main culprits are the base acreage and established yield provisions of those programs, which reward farmers for using as much of their land as they can to grow program crops. Government price supports above the market prices for those crops amplify the inducement to grow those crops and postpone a shift to rotations and other low-input practices. Most observers expect that Congress will soon consider ways to remove or lessen these barriers.

And adopting low-input farming has other possible institutional barriers. Among them I would have to cite the mission, organization, and culture of the USDA, land grant universities, and other members of the agricultural community. The mixed response of the community to the new LISA research and education program is only one kind of barrier. These institutions have played a central role in developing conventional agriculture. The idea of farming with fewer or no purchased chemicals is alien to their way of thinking. It is just not easy for them to now view objectively a new way of thinking about agriculture, especially one that emerged as criticism of conventional farming.

Incentives. Farmers' access to facts and information and the removal of existing barriers to adoption of low-input agriculture should come before incentives, and may significantly lessen the need for them. I am not sure what we are assuming about the means and ends of incentives. If we are saying that some compensation may be needed during the transition period, that is one thing. If we mean that low-input farming, once adopted, is still destined to remain less profitable than conventional agriculture, I wonder. Certainly, we need to look carefully at the rationale for incentives as well as the kinds of incentives that would make sense.

Regulations. I tend to think of regulations as last resorts. At the same time, the possibility of their being used can boost substantially the willingness of farmers, as well as input manufacturers and suppliers, to consider low-input substitutes. The regulatory approach also can include raising the cost to farmers of inputs and practices that do not enhance sustainability.

Taxing fertilizer sales, as is now done in Iowa, is an example. Another would be to deny farmers eligibility for benefits of certain government programs if they do not use low-input practices (low-input cross-compliance). These are not easy steps to take. The experience so far with conservation cross-compliance should help to shed light on the feasibility of such an approach in the case of low-input sustainable farming.

The challenge

To repeat the question: Will low-input sustainable farming become mainstream agriculture? The biggest uncertainty in my mind is whether profitable production will in fact overshadow the other ends of sustainability. The question is: Will the marriage of profitable production, conservation, environmental quality, and food safety and quality turn out to be only a courtship or, at best, a brief marriage of convenience?

How much of the current interest in sustainability traces mainly to the promise it has offered for reducing costs? Will that interest quickly fade if the prices of corn, wheat, and other crops rise substantially or the government supports them above market price levels? "Yes" is often the answer heard. A recent article in USDA's *Farmline* magazine puts it this way: "If environmental issues are to have higher priority and if greater use of low-input production methods is to be achieved,...some form of government intervention might be necessary. But...regulation and other forms of direct intervention to change price signals could be ineffective if agriculture experiences another boom in export demand and commodity prices. Under these conditions, it would be even more difficult to achieve the goals of maintaining profits and a competitive international market position, while also improving environmental conditions" (*3*).

I do not mean to say that profitability is inherently at odds with the overall sustainability of agriculture. William Reilly has wisely reminded us that poor farmers can also be poor environmentalists (*5*).

My concern is that beyond the point where economic and environmental ends are comfortable companions, we could see the entrepreneurial, profit-making drive taking over the reins. It is too deeply rooted in our culture and the economic thinking that shaped it too pervasive for many people to now accept a profoundly new philosophy of sustainability as just around the corner. The point is captured by these words in a recent *Farm Journal* editorial on low-input, sustainable agriculture: "The only sustainable agriculture is profitable agriculture. Short and sweet" (*2*).

Don't let these thoughts fuel pessimism. See them instead as a challenge. The challenge is not to ignore the prevalence of self-interest in our culture but, rather, in every way possible to help increase the enlightenment of that self-interest. Today's climate could make that easier than it has been for some time. We should be encouraged by what President George Bush said in his inaugural address—that our worth is not measured only by our wealth, that we need to temper our pursuit of self-interest and work toward a kinder and gentler society.

We should talk about how to capitalize on this climate. We should think of ways to increase consideration of sustainability as a noble purpose, in our school systems, in 4-H programs, and elsewhere among public and private groups. We should increase our efforts to reward conservation and low-input, sustainable farming just as we have always rewarded higher yields and output in agriculture.

Every person across this land has a stake in the outcome. Sustainable agriculture is not just an idea whose time has come. It is an ideal we now have the privilege to examine and uphold for all to consider.

REFERENCES CITED

1. Ainsworth, Earl. 1989. *LISA men have called you.* Farm J. (2): 1.
2. American Society of Agronomy. 1989. *Agronomy news.* Madison, Wisc.
3. Foulke, Judith. 1989. *Low-input farming faces profitability issue.* Farmline (2): 13.
4. Leopold Center for Sustainable Agriculture. 1989. *Descriptive brochure.* Iowa State Univ., Ames.
5. Reilly, William E. 1987. *Agriculture and conservation: A new alliance.* J. Soil and Water Cons. 42(1): 17.
6. Rodale, Robert. 1984. *Alternative agriculture.* J. Soil and Water Cons. 39(5): 294-296.
7. Rodale, Robert. 1989. *Conservation is dead.* The New Farm (2): 10-13.
8. Van Meter, Donald E. 1988. *Conservation in transition: The issues.* J. Soil and Water Cons. 43(3): 210.
9. Worster, Donald. 1985. *A sense of soil: Agricultural conservation and American culture.* Agriculture and Human Values 2(4): 30.
10. U.S. Department of Agriculture. 1980. *Report and recommendations on organic farming.* U.S. Gov. Printing Off., Washington, D.C. □

Low-input, sustainable agriculture: Myth or method?

By Charles W. Stenholm and Daniel B. Waggoner

FOR more than 50 years, federal resource conservation efforts have concentrated on two goals: reducing soil erosion and developing water resources to protect and enhance agricultural productivity. By the early 1980s, Congress had created more than two dozen programs to address these goals. Yet, there is a growing perception among certain parties that these programs are inadequate in addressing national soil erosion and water quality problems (*5*). Furthermore, U.S. agriculture, long the symbol of a wholesome America, has become linked to a variety of environmental concerns (*4*). While agriculturally related environmental issues have traditionally been debated primarily within the House and Senate agriculture committees, other congressional panels with expanding environmental agendas are increasingly addressing issues affecting agriculture—from their own perspectives (*4*).

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Some background

The Agricultural Productivity Act, passed as part of the 1985 Food Security Act, provided the authority to conduct research and education programs in alternative farming systems—often referred to as low-input, sustainable agriculture (LISA). In December 1987, Congress appropriated $3.9 million to begin work under this act. More specifically, the Agricultural Productivity Act mandates scientific investigation to (a) enhance agricultural productivity, (b) maintain land productivity, (c) reduce soil erosion and loss of water and nutrients, and (d) conserve energy and natural resources.

Most of the funded LISA projects are long-term studies requiring several years of development and application before scientifically meaningful results can be obtained (*25*). The goal of the program is to provide an abundance of food and fiber in a way that is harmless to humans and the environment and sustainable for generations to come. The projects are designed to help farmers substitute management, scientific information, and on-farm resources for some of the purchased inputs they currently depend upon for their farming enterprises. In fiscal year 1989 some 56 projects were approved of 431 proposals received (*25*).

Recognizing the mounting concern about resource conservation and its relationship with broader environmental problems, legislative responses could take many forms, including amendments to existing conservation programs, new conservation provisions in the 1990 farm bill coupled with commodi-

ty program participation requirements, or separate legislation by the congressional agriculture committees. Responses might be limited to traditional soil and water conservation efforts, or they could include provisions addressing groundwater pollution, water quality and supply problems, and the potential for low-input, sustainable agriculture (*5, 19*).

Agricultural and environmental interests are interacting in a growing number of ways and often with increasing intensity. Interactions can be seen at all scales, from the national level in policy debates before Congress to the local level where farmers are pressured increasingly to be aware of environmental concerns associated with their activities (*28*).

The agricultural community will face a difficult task if it attempts to convince most people that old programs, policies, and approaches are adequate in addressing environmental problems of the 1990s. The perception of an inadequate federal response will certainly set the stage for a more vigorous state regulatory role and a more aggressive posture by other congressional committees concerned principally with environmental protection and public safety.

An interesting thematic tug-of-war is likely to unfold during the 1990 farm bill debate within the environmental-conservation community. Fewer people involved in production agriculture means fewer people understand production agriculture (*22*). Therefore, those involved in production agriculture need to educate environmentalists about key linkages so that reforms adopted in 1990 will accomplish domestic environmental objectives, support farm income, and strengthen the nation's posture within the General Agreement on Tariffs and Trade (GATT) talks.

Although few on Capitol Hill are ready to speculate on what specific LISA-related concepts may end up in the 1990 farm bill, some emerging ideas include (a) permitted planting of other crops on farm program base acres in lieu of set-asides; (b) phasing-in of a limited multiyear set-aside that would allow low-impact uses, such as livestock grazing; (c) a variation of the 0/92 program that would allow more flexibility for using set-aside acreage; and (d) deficiency payments decoupled from yields (*19*).

Many farm groups and farm state representatives recognize the need to support practices that encourage long-term farm productivity and profitability. Certainly, increased attention focused upon groundwater quality protection, agrichemical residues, and unmet soil conservation needs have given the LISA concept momentum.

To be sure, Congress will be faced with several interrelated questions as it debates provisions in the next farm bill and in other legislation that addresses these relationships. Some of these questions center on whether traditional soil conservation programs can be expanded to accommodate broader environmental concerns or whether new programs are needed. More specifically, the question is whether the programs created in the 1985 farm bill are the appropriate vehicles for tackling a wider range of issues (*5*).

It is because of a progressive agriculture that Americans enjoy the standard of living and food abundance that are the envy of the world (*21*). However, concerns about the environment are calling for changes in farming practices and input use. To make significant changes in present practices, farmers and ranchers must deal with several obstacles, including time limitations, knowledge and information limitations, new technology implementation, and the need to increase efficiency in crop production (*1*). Moreover, reconciling generally accepted agricultural practices with environmental and conservation goals has become one of the most significant challenges confronting farmers and ranchers. No one is more dependent upon a healthy and safe environment than are farmers and ranchers who make their home and their living from the land (*14*).

Based on questions over the past several years, we know that producers are searching for ways to reduce production costs. Currently, there are serious and legitimate concerns about the off-farm environmental effects of agricultural practices as well as effects on health and safety of farm families (*9*). With this in mind, one of the most frequent words used in agricultural and other biological circles on the current Washington scene is sustainability.

Defining sustainability

Agricultural sustainability can be defined in different ways and sought through different means (*6, 19*). Sustainability is only a target toward which one can aim, and agricultural systems obviously operate within the constraints of the larger society (*3*). While low-input, sustainable agriculture is the current buzzword in the nation's capital, the term's precise meaning remains elusive.

Part of the current confusion about the sustainable agriculture concept is that several related ideas and terms about sustainable agriculture have also been used. Given the limited understanding of what defines true sustainability, it is no easy task at this point to determine how to incorporate the ideas of sustainability into congressional policy efforts. And on the local scene, the principal cause of the observed reluctance of many farmers to adopt sustainable techniques, even techniques that have been demonstrated to be cost-competitive on a per-acre basis, is the set of institutions (policies, laws, and property rules) that have grown up around contemporary, conventional systems (*15, 19*).

Does calling a system low-input guarantee that it is sustainable? And if it is sustainable—that is, capable of enduring—is it necessarily alternative—meaning it is different from prevailing practices? Is an agricultural system that allows for reduced inputs necessarily ecological, that is, more like a natural ecosystem? In much of the literature there is an implicit assumption that when one strives for any of these goals the others somehow come along automatically. There is little recognition that these goals are substantially distinct and independent, so that each has to be achieved in its own right (*18*). The term sustainability has agronomic, environmental, social, economic, and political dimensions. It is not merely a set of best management practices or simply a reduction in the use of agrichemicals. It is site-specific, management-intensive, and resource-conserving. It considers long-term as well as short-term economics because sustainable is readily defined as forever, that is, agricultural environments that are designed to promote endless regeneration (*13*).

Information management the key

Many recent studies have shown that a key obstacle to widesspread adoption of low-input, sustainable principles and practices is the lack of reliable information (*16*). An important reason why such information is inadequate is that there are few market incentives encouraging anyone to develop and disseminate such information. Low-input farming strategies are an example of what economists call public goods. Unlike private goods, such as agrichemical products and related services, crop management strategies are difficult or impossible to restrict or control as proprietary information. This creates a problem of patentability that makes it difficult to profit directly from developing or promoting low-input methods (*7*). Furthermore, even with all of the information for a given system, a meaningful national low-input, sustainable agriculture technical guide may be improbable because of local factors and constraints. Transitions from present production to systems with lower inputs will require change by evolution rather than revolution if the changes are to be truly sustainable. The set of strategies for a given production unit is site-specific and changes at a given site over time because of the random dynamics of the natural environment

(*17*). There are institutional obstacles to the adoption of environmentally safe production methods. An example is farm program base acreage requirements that reduce producer flexibility and encourage monoculture while limiting crop rotations (*19*). Consequently, the planting flexibility question needs to be placed on top of the commodity program agenda during deliberations surrounding the 1990 farm bill.

Coupled with this lack of basic information and producer flexibility is a shortage of research information that addresses the technology needed to respond to problems where they do exist. Economically viable production practices that avoid or minimize pollution from agriculture need to be developed. This is not an easy or short-term task. Regrettably, we simply do not have a reliable data base to help us understand the nature and extent of the problem from a national perspective (*10, 19*). However, simple reliance on agrichemicals and related technologies is not a substitute for good stewardship. Long-term economic viability and environmental protection in agriculture depends ultimately upon both expanded use of better technology and improved education, crop rotation, economic farm management, and integrated pest control (*19*).

Production practices contained in the low-input production philosophy, such as integrated pest management (IPM) and best management practices (BMPs), are positive steps in the right direction. IPM allows farmers to wisely use chemicals through accurate insect identification and timely application. However, many producers have been slow to adopt IPM because it requires greater management time and skills. Nonetheless, the Office of Technology Assessment estimates that U.S. farmers could reduce pesticide use by as much as 75 percent if IPM programs were adopted widely (*20*). Available data indicates IPM programs have reduced pesticide use by 20 to 50 percent in numerous cropping systems (*19, 26*). IPM programs currently have impacts on more than 30 million acres, resulting in estimated annual net benefits of more than $500 million (*19, 26*).

In addition, evidence indicates that farmers who adopt BMPs are able to reduce nitrogen fertilizer application rates on corn by as much as half with no reduction in yield (*7*). BMPs themselves evolve over time, changing to reflect new technical understanding of erosion and other environmental problems; the recognition of new issues, such as water quality and groundwater contamination; and shifting economic situations.

As with any technology, however, there is a cost. Multiple cropping and conservation tillage both require more intensive management than do conventional tillage and monoculture (*24*). Moreover, there is no free lunch when it comes to maintaining soil supplies of mineral nutrients, such as phosphorus and potassium. The nutrients removed from the soil in harvested crops must be replaced or soil fertility will decline. It has

A BRIEF HISTORY OF SUSTAINABLE AGRICULTURE

Conservation and low-input agriculture are operating in the same ballpark. Both are ideas for the protection and improvement of agriculture. Both concepts also involve a set of specific methods to make sure that agriculture is able to achieve long-term goals for the protection of its resources, for its economic success, and for human satisfaction.

Yet both are quite different ideas. Each has its own history. Conservation as an idea and method stems from the creative thinking and the actions of Gifford Pinchot shortly after the turn of the century. Everyone who is active in the conservation movement should, in my opinion, read Gifford Pinchot's autobiography to get a good sense of the history of this important method.

The low-input, sustainable agricultural approach dates its history to another book published about the same time—Franklin H. King's *Farmers of Forty Centuries*. King compared the low-input and sustainable approach of oriental agriculture with what he perceived as the profligate set of methods American farmers were using.

Briefly, King's message to the American agricultural community was that farming systems have within themselves a large capacity to regenerate, using internal resources. Those are not King's exact words, but they are more modern terms that express his central idea. King was not against the use of external inputs, such as artificial fertilizers. But he warned that an agriculture that was not rooted firmly in frugality and the recycling of fertilizer elements and organic materials could not last. It would not be sustainable over the long term in either economic, biological, or cultural terms.

Unfortunately, King died before he could write the last chapter of his book, which he meant to be a specific warning to the West that sustainable practices would be vital to farming's health in the future. But other people were influenced profoundly by *Farmers of Forty Centuries.*

Sir Albert Howard, the founding scientist and philosopher of what we now call organic farming, cites King's work in his book *An Agricultural Testament.* My own life and work has been oriented around the issues and possibilities that King presented so eloquently in 1907. In fact, I am convinced that one of the major reasons that low-input, sustainable agriculture is now perceived as an effective method to respond to the agricultural problems of the 1980s is that the technique is firmly rooted in the good work of several generations of leaders.

Now, we are seeing a coming together of conservation and low-input, sustainable agricultural thinking. My message, in fact, is that I see great potential for a marriage of the two ideas. When I spoke a few years ago at the annual meeting of the Soil and Water Conservation Society, I argued for a marriage of conservation and agriculture itself—a combination of what I saw as two separate ideas into a set of regenerative agricultural systems. Some steps were taken in that direction. SWCS and the Rodale Institute cosponsored a meeting that came to be known as the "marriage conference." It was one of the first roundtables at which high officials of the U.S. Department of Agriculture, the conservation community, and the regenerative agriculture community sat down together to talk about the future of cooperation. Many initiatives that are now bearing fruit got their start at that meeting.

In the last few short years, the low-input, sustainable agricultural approach has gained tremendously in stature, accomplishments, and the number of adherents. There is now a much greater body of evidence showing not only that low-input, sustainable agriculture works, but how it works and how it can be applied in wider agricultural situations.

At the same time, I think there is a growing realization by leaders of the conservation community that steps need to be taken to, in effect, reinvent what conservation is. Originally, in Pinchot's vision, conservation was a unified set of wise management methods—unified in the sense that it penetrated to all aspects of the management system for natural resources. I believe that in the later years of the history of conservation it has become more of a method to correct the problems of agriculture rather than a total partner in the whole equation. Farmers too often look at conservation as a set of methods that are "the right thing to do" to correct erosion, pollution problems, and other troubles caused by agriculture—if the government helps pay for them. That way of thinking has gradually led to a lack of enthusiasm with the central idea of conservation, which radiated so clearly from the work of the early thinkers and activists, such as Pinchot and Hugh Hammond Bennett.—***Robert Rodale,*** *Rodale Institute, Emmaus, Pennsylvania, speaking at "The Promise of Low-Input Agriculture" conference.*

been suggested that simply producing legumes and spreading manures could achieve crucial soil improvement objectives on poor soils. However, the quantities of manure required would be difficult to economically acquire, and it would be near impossible to get useful legumes to grow without extensive use of soil amendments.

Sound fertility management uses available livestock manures and crop rotations wherever practical, taking appropriate nutrient credits for these materials, then using commercial fertilizers to balance the crop needs for realistic yield goals (*22*). In summary, better farming means balancing ecologic, social, and economic considerations for short-run survival and long-run sustainability. Better farming will require more research and information that is relevant to a balanced approach to farming (*12*).

We are approaching the tailor-making stage in some areas of crop protection chemical research. Compounds are being developed that are designed intricately to disrupt plant and insect processes at sites within these systems that will be unique to them. Potential developments in biotechnology may open windows of opportunity in crop productivity and plant protection that are difficult to conceive of today (*9*). Proper education will play a critical role in determining how consumers react in the next decade as producers begin to use these new technologies (*14*).

A prosperous agriculture no longer implies a prosperous rural community (*6*). The rural social fabric must be strengthened if the United States is to maintain rural communities, which are the support base for farmers and their families (*3*). Sustainability is as important for rural communities as for individual farmers. Sustainable economic development for rural communities is based on realization of the value inherent in geographically fixed resources in ways that conserve the nonrenewable resource base, protect the physical and social environment, and provide an acceptable level of economic return for those who work and live in the community (*12*).

A new term proposed along with sustainable agriculture is thought-intensive agriculture. It means to think carefully about all available strategies in the farm system that can deal with the problem and create production opportunities (*11*). Rural families and communities need to examine their own needs and goals and carefully search out an approach that will help them to meet these goals, consistent with the available resource base (*9*). Thinking from this perspective leads one to believe that we must balance our economic needs, in terms of production and profitability; our environmental needs, in terms of resource conservation and protection; and our social needs, in terms of rural community vitality and the well-being of farm families (*3*). No single set of currently available systems and technologies should claim to hold an exclusive key to the ultimate, long-term goal of agricultural sustainability. Merely labelling a particular production method as sustainable does not guarantee that it is, nor does the label mean that some other approach, or future combination of emerging technologies, cannot contribute to the goal of sustainability (*27*).

Continuing global concerns

World population growth and competition from foreign agricultural production will continue to be major challenges for U.S. farmers (*2, 19*). In 1985, the world's population was about five billion. By the end of this century, experts estimate that it will reach six billion, an annual growth rate of almost two percent. The general public, especially the urban part of it, does not understand that if U.S. farmers used the agricultural technology of the 1930s and 1940s to produce the harvest of 1985 they would have to convert 75 percent of the permanent pasturelands in the U.S. or 60 percent of American forests and woodland areas to cropland. Thankfully, relative to other parts of the world, U.S. consumers spend a very small portion of their disposable income on food. And this is accomplished with less than two percent of the U.S. population working on farms (*19*).

The productivity of modern agriculture is the result of a remarkable fusion of science, technology, and practice (*23*). The conventional agriculture of today is not the conventional agriculture of even five years ago. Technology and science have moved forward and created new opportunities and new awarenesses (*10*). The long history of agronomic research that forms the basis of today's progressive production practices is scientifically sound and has withstood the test of fluctuating economic conditions. This record of technological accomplishment has convinced many people that scientific research and development, if properly nurtured and developed, can be counted on to increase future productivity at least as rapidly as in the past (*6, 19*).

Today's farmers are searching for resource-efficient, lower cost, and more profitable production systems. Everyone in agriculture should share the broader concerns of society for a clean and livable environment. There is also no doubt that new directions should be pursued to assist in the adaptation to future changes in resource availability and societal awareness of environmental issues (*9*).

Environmental protection cannot take a back seat to profit; farmers must be encouraged and allowed to manage an efficient system that preserves the quality of their drinking water while also preserving their standard of living. Subsequently, a multiscience approach—including interdisciplinary team efforts, meaningful participation of operating farmers, and involvement of public and private organizations—is essential to the continued success of production agriculture. To be economically sustainable, agriculture must produce a marketable product at a lower cost than the market is willing to pay (*11*). Unfortunately, there is much unknown about the relationship between specific technologies and the actual sustainability of an agricultural system. Until we have a better understanding of this relationship, it would seem premature to inflexibly associate sustainable agriculture with any one class of techniques (*27*).

We need to search for alternative approaches that are more broadly based, to bring in more ideas and broaden the ownership of the low-input, sustainable agriculture research agenda. Working as a team, producers, extension agents/specialists, and researchers can identify priority areas where more information is needed and together can search for a range of alternative solutions (*9*). Furthermore, greater diversity in both our crop and livestock systems often can lead to improved economic stability for producers. It seems we have only begun to tap the rich pool of products that could be produced efficiently from agricultural species. Because farmers sometimes feel they are caught in a squeeze between weather and markets, it can be psychologically helpful to ensure that they have plenty of options to choose from and different potential profit sources (*3*). Technology—intelligently conceived and carefully implemented, including the measured and careful application of agrichemicals and crop protection techniques—represents the hope for the future and, as such, should be a cornerstone of food and agricultural policy for the coming decades (*21*).

Sustainable agriculture is not so much a new idea as a synthesis of ideas originating from various sources, out of various motivations (*18*). A new emphasis on sustainable agriculture does not mean going back 50 years to a less complicated agriculture (*9*). People with a particular view of what sustainable agriculture is all about sometimes are not willing to acknowledge that other versions may be equally legitimate (*18*). There are many paths to a sustainable agriculture; it is not so important which path is selected, but rather that the path leads to the

desired goal—a healthy agriculture that can be passed on to future generations (*17*).

Most importantly, if a farming method is not profitable, it cannot be sustainable. If producers are to adopt methods that result from a low-input concept, the technology must be based on more than a whim and a promise. Information and education obviously should be a part of any new government program related to sustainable agriculture (*12*). Sustainable systems must be resource-conserving, environmentally sound, socially supportive, and commercially competitive. Rural schools, banks, supply stores, elevators, and hospitals are crucial to improving the overall sustainability of our agricultural sector (*3*). The socially optimal balance between ecology and economics must be derived farm by farm, crop by crop, and field by field.

In conclusion

In the long run, there is no conflict between the ecologic, social, and economic dimensions of sustainability. A system must be ecologically sustainable or it cannot persist over the long run and thus cannot be productive and profitable. A system must be productive and profitable over the long run or it cannot be sustained economically, no matter how ecologically sound it is (*12*).

At present, low-input farming is still more a philosophy and spirit of farming than an easily defined set of principles. The objectives of a clean environment and a sustainable production system are important and desirable goals. Modern, progressive agriculture—farmers and agribusiness—need not be defensive on this issue. A positive, forward-looking approach is much more appropriate and acceptable, and necessary, to the overall well-being of all sectors in the agricultural business community.

The challenge of the 1990s will be to strike a reasoned balance between competing interests and goals. The 1990 farm bill will have to be responsive to all legitimate goals. The issue is whether it will do so in a systematic and thoughtful way that gives the U.S. Department of Agriculture and farmers the policy tools and flexibility needed for the problems of the 1990s. Flexibility in new programs and policies will be essential to allow more creative, ambitious, profitable, and locally acceptable strategies to emerge that underwrite major progress toward reconciling stewardship and agricultural production needs and responsibilities (*19*).

Certainly, the 101st Congress will tackle agriculture's research and stewardship challenges under progressively tighter fiscal constraints. However, if Congress wants all farmers to have an opportunity to use new farming systems, it must assist limited resource farmers to expand their management skills. For farmers who don't fit the early adopter profile, it will be important that federal policymakers put forth an extra effort to make sure they have access to the resources needed for the successful adoption of innovations (*14*).

There is a need to better coordinate the work and programs of the many federal, state, and local organizations and the private sector involved in researching and promoting environmentally safe production practices (*10*). We must remove all institutional barriers and disincentives that prevent producers from taking advantage of improved agricultural methods (*8, 19*). A complete understanding of alternatives via research and the implementation of proven alternatives through educational programs have potential for a more sustainable agriculture than legislative mandates (*17*). These methods should be based on proven science and sound agronomic research, and they should incorporate modern technology to the fullest.

Many of the issues raised here, which have international as well as domestic dimensions, will be addressed during the deliberations now beginning on a 1990 omnibus farm bill, where resource conservation and environmental protection could be a key title (*4*). Hopefully, in the course of the debate over the 1990 farm bill, the facts about the limitations of the low-input, sustainable agriculture management strategies will be brought out, the positive aspects of the low-input, sustainable agriculture program will be identified, and a plan that can be acceptable to mainstream agriculture will be developed. But mainstream agriculture—farmers and agribusiness—cannot afford to sit on the sidelines. All must get involved in the legislative process to ensure their interests are represented properly. Failure to do so will contribute to the decline of one of the few industries in the United States that has managed to retain world-class status and is capable of continuing to be highly competitive in world markets.

REFERENCES CITED

1. Beck, R. H. 1989. *Statement presented before the U.S. Senate Agriculture Subcommittee on Conservation and Forestry, June 22, 1989.* Washington, D.C.
2. Bickel, L. 1974. *Facing starvation: Norman Borlaug and the fight against hunger.* Reader's Digest Press, New York, N.Y.
3. Brown, G. E. 1989. *The critical challenges facing the structure and function of agricultural research.* J. Production Agr. 2: 98-102.
4. Congressional Research Service. 1989. *Agriculture and the environment.* The Library of Congress, Washington, D.C.
5. Congressional Research Service. 1989. *Soil and water conservation issues in the 101st Congress.* The Library of Congress, Washington, D.C.
6. Douglass, G. K. 1984. *The meanings of agricultural sustainability.* In *Agricultural Sustainability in a Changing World Order.* West View Press, Boulder, Colo. pp. 3-29.
7. Fleming, M. H. 1987. *Agricultural chemicals in ground water: Preventing contamination by removing barriers against low-input farm management.* Am. J. Alternative Agr. 2(3): 124-130.
8. Fowler, W. 1989. *Farm conservation and water protection act.* Congressional Record: S.5,164-5, 166.
9. Francis, C. A., J. W. King, D. W. Nelson, and L. E. Lucas. 1988. *Research and extension agenda for sustainable agriculture.* Am. J. Alternative Agr. 3(2,3): 123-126.
10. Hess, C. E. 1989. *Statement presented before the U.S. Senate Agriculture Subcommittee on Conservation and Forestry, June 22, 1989.* Washington, D.C.
11. Hoeft, R. G., and E. D. Nafziger. 1988. *Sustainable agriculture.* In Proc., Illinois Fertilizer Conference. Univ. Ill., Urbana-Champaign, 2 pp.
12. Ikerd, J. E. 1989. *Statement presented before the U.S. House Agriculture Subcommittee on Department Operations, Research, and Foreign Agriculture, July 19, 1989.* Washington, D.C.
13. Keeney, D. R. 1989. *Statement presented before the U.S. House Agriculture Subcommittee on Department Operations, Research, and Foreign Agriculture, July 19, 1989.* Washington, D.C.
14. Kleckner, D. L. 1989. *Statement presented before the U.S. Senate Agriculture Subcommittee on Conservation and Forestry, June 22, 1989.* Washington, D.C.
15. Klor, D. 1989. *Statement presented before the U.S. Senate Agriculture Subcommittee on Conservation and Forestry, June 22, 1989.* Washington, D.C.
16. Krome, M. 1989. *Statement presented before the U.S. Senate Agriculture Subcommittee on Conservation and Forestry, June 22, 1989.* Washington, D.C.
17. Laughlin, C. W. 1989. *Statement presented before the U.S. Senate Agriculture Subcommittee on Conservation and Forestry, June 22, 1989.* Washington, D.C.
18. Lockeretz, W. 1988. *Open questions in sustainable agriculture.* Am. J. Alternative Agr. 3(4): 174-181.
19. National Research Council. 1989. *Alternative agriculture.* National Academy Press, Washington, D.C.
20. Office of Technology Assessment. 1979. *Pest management strategies.* Rpt. No. OTA-F-98. U.S. Gov. Printing Off., Washington, D.C.
21. Office of Technology Assessment. 1988. *Technology and the American economic transition: Choices for the future.* Rpt. No. OTA-TET283. U.S. Govt. Print. Off., Washington, D.C.
22. Reetz, H. F., P. Fixen, and L. Murphy. 1989. *LISA-the industry perspective.* In Proc., 40th Annual Far West Regional Fertilizer Conference. Potash and Phosphate Inst., Atlanta, Ga.
23. Ruttan, V. W. 1988. *Sustainability is not enough.* In *Symposium on Creating a Sustainable Agriculture for the Future.* St. Paul, Minn.
24. Stinner, B. R., and J. H. Garfield. 1989. *The search of sustainable agroecosystems.* J. Soil and Water Cons. 44(2): 111-116.
25. U.S. Department of Agriculture. 1989. *LISA 88-89: Low-input sustainable agriculture research and education projects funded in 1988 and 1989.* Washington, D.C.
26. U.S. House Committee on Government Operations. 1988. *Low-input farming systems: Benefits and barriers.* Rpt. No. 100-1097. Washington, D.C.
27. Youngberg, I. G. 1989. *Statement presented before the U.S. House Agriculture Subcommittee on Department Operations, Research, and Foreign Agriculture, July 19, 1989.* Washington, D.C.
28. Zinn, J. A., and J. E. Blodgett. 1989. *Agriculture versus the environment: Communicating perspectives.* J. Soil and Water Cons. 44(3): 184-187. □

Agriculture's search for sustainability and profitability

Tradeoffs between resource conservation and environmental soundness and productivity and competitiveness are the key in the search for sustainable agricultural systems

By John E. Ikerd

ARE sustainable systems necessarily profitable? Are profitable systems necessarily sustainable? The answers to these questions depend on whether one talks about the long or short run or about an individual farm or society in general.

Sustainability, by definition, is a long-term concept. The term sustainability, as used here, refers to farming systems that are capable of maintaining their productivity and utility indefinitely. Sustainable systems must be resource-conserving, environmentally compatible, socially supportive, and commercially competitive.

Systems that fail to conserve the resource base eventually lose their ability to produce. Systems that fail to protect the environment eventually destroy their reason for existence. Farming systems that fail to provide an adequate food supply at reasonable costs lose their utility to society. And finally, systems that are not commercially competitive will not generate the profits that are necessary for economic survival.

A system must be profitable in the long run or it cannot be sustained. A system must be sustainable or it cannot be profitable in the long run. Some may quibble about the philosophical concept of long run and at what point in time sustainability and profitability converge. But most would agree that in the long run there is no conflict between sustainability and profitability.

Even in the short run, there is no conflict between sustainability and profitability from the standpoint of society as a whole. Societies that exploit resources and degrade the environment for unsustainable, short-run benefits are not profitable from the standpoint of society as a whole. They create an illusion of productivity and profitability by failing to consider all social costs. One segment of society bears the costs that another segment ignores, or one generation bears the costs that a previous generation failed to consider. Social benefits exceed costs only for those systems that also are sustainable.

The conflict between sustainability and profitability arises for individual producers in the short run. Profitable individual farming systems may or may not be sustainable in the long run. Also, sustainable, individual farming systems may or may not be profitable in the short run. Thus, a conflict may arise that forces farmers to choose between short-run profit maximization and long-run sustainability. This potential conflict is the root of most economic issues related to low-input, sustainable agricultural systems.

A sustainable, individual farming system must be able to survive short-run losses due to periodic crop failures or depressed markets that characterize the agricultural sectors of most economies. Thus, sustainable farming systems may be unprofitable, at least at times. In fact, sustainable farming systems may be less profitable than unsustainable alternatives, even for extended periods of time.

Farmers may generate short-run profits by mining or wasting the resource base, degrading the environment, or exploiting the consuming public. Such systems are not sustainable in the long run, but they may well be profitable, even most profitable, for extended periods of time.

This potential conflict between long-run sustainability and short-run profitability is perhaps the most significant question confronting U.S. farmers today.

Are low-input systems sustainable?

Low-input, sustainable agriculture is a relatively new term and, thus, has no universally accepted definition. The term actually embodies two separate concepts: low-input and sustainable agriculture. These two terms do not mean the same thing.

The term "low input," as used here, means systems that rely less on external, purchased inputs and more on internal resources (*10*). Some people add other qualifications to purchased inputs, such as nonrenewable energy, inorganic, or synthetic inputs (*3*). These qualifications add clarity in some contexts but add confusion in others. The broader concept of inputs, which includes all external or purchased inputs, is used here unless otherwise specified.

There is no clear division or point of separation between low-input and high-input farming systems. Thus, *lower* input rather than *low* input might be a more appropriate

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term. Systems become lower input ones over time as they increase their reliance on productivity from internal resources and reduce reliance on purchased inputs. Higher input systems substitute external inputs for internal resources instead. Lower input, like profitability, can be viewed either in the long run or short run.

Lower input systems may or may not be more sustainable than higher input, conventional farming systems. Lower input systems tend to be more resource-conserving and environmentally compatible than conventional systems that rely more on external purchased inputs. Thus, if the socioeconomic dimensions of sustainability are ignored, low-input may appear to be synonymous with sustainability.

However, the socioeconomic issues of sustainability cannot be ignored. Questions regarding sustainability of lower input systems tend to focus on their productivity or ability to support growing populations and on their commercially competitiveness with higher input systems. Continuing profitability tends to reflect both productive efficiency and commercial competitiveness.

Systems that are both lower input and sustainable must measure up to socioeconomic standards of productivity and competitiveness, in addition to resource conservation and environmental soundness. Neither lower inputs nor higher profits alone are adequate short-run measures of sustainability.

In some cases, lower input systems may also be higher profit systems, even in the short run (*2*). In many cases, however, farmers may be forced to choose between systems that are more resource-conserving and environmentally sound and alternative systems that are more productive and commercially competitive.

The search for sustainability in agriculture, in a practical sense, is the search for an acceptable balance between lower external inputs and greater profitability.

Are we going backward?

Critics of low-input, sustainable agricultural systems point out similarities between lower input systems and earlier conventional agricultural systems. They have observed the positive correlation between greater reliance on purchased inputs and greater agricultural output at lower costs. Does lower input mean lower output? Aren't low-input, sustainable agricultural systems really farming systems of the past rather than farming systems of the future?

U.S. farmers have persistently increased their reliance on purchased inputs over the past several decades because of the need to reduce costs, remain competitive, and pursue greater profitability in their farming operations. Conventional, higher input farming systems have become conventional, that is, widely adopted, in large part because farmers were motivated by the promise of greater profitability.

Efficiency gains from specialization generally have been recognized and widely accepted for centuries as an economic fact of life. Profitability from higher input farming systems has come in no small part from realization of gains from specialization. Commercial fertilizers and synthetic pesticides allowed farmers to abandon crop rotations and mixed livestock, cropping systems in favor of more specialized cropping and specialized livestock systems. Low energy prices also allowed economic use of larger, more specialized equipment and production facilities that encouraged greater specialization.

The trend toward greater reliance on external inputs has not been limited to commercial fertilizers and pesticides or nonrenewable, energy-based inputs. Specialization also has facilitated greater use of specialized, hired labor. And it has allowed farmers to acquire more specialized knowledge bases and management skills, sometimes taking the form of paid consultants. The shift toward greater reliance on these particular external inputs has important but often ignored implications for socioeconomic sustainability.

Farming seemed to be following the specialization trends of other sectors of the economy. Farms were becoming factories without roofs; specially trained people performing specific tasks at specific times; assembly lines dictated by weather; farmers following recipes that specify varieties, tillage practices, fertilizers, irrigation schedules, pesticides, and harvest times required to produce a quality-controlled product.

Why consider changing that trend? Low-input, sustainable agriculture implies diversification rather than specialization. Such systems require broad knowledge rather than

specialized information or training. They require judgment and flexibility rather than assembly-line repetition. There are no recipes for successful low-input, sustainable agricultural systems.

Old concepts with new technologies. A return to more diversified, less specialized farming systems does not necessarily mean a return to farming systems of the past. A wide range of technology is available today that was not available to farmers 40 or 50 years ago. Farmers who use low-input, sustainable agricultural systems now may be able to use many of those technologies to enhance the productivity of internal resources, thus reducing dependence on external inputs.

First, low-input, sustainable agriculture does not imply total elimination of external inputs, only lower use of external inputs. Thus, low-input, sustainable agricultural systems that use environmentally compatible level of fertilizers and pesticides and nonrenewable energy conservatively may be far more productive and profitable than similar systems of 40 years ago.

Microcomputers represent a new technology that holds great promise for old farming systems. Computer setups costing less than $3,000, for example, give farmers access to more computing power than that available to most large corporations less than three decades ago. Microcomputers can complement and enhance the farmer's management abilities, allowing him or her to effectively substitute information and knowledge for purchased inputs.

A farmer with a computer can plan, organize, direct, and control the most complex of farming systems. Today's farmers can apply logic and scientific knowledge to systems that farmers of the past managed mostly by intuition and guesswork.

Modern mechanization likewise opens new opportunities for farmers to apply old, tried, and proven principles. No-till and low-till farming equipment not only conserve and enhance the soil resource but make intercropping systems more feasible and potentially profitable. Deep-tillage systems can improve drainage and inherent productivity of soils and reduce water quality risks. Modern electric fencing makes intensive grazing systems economically practical, enabling possibly greater returns from forages used in crop rotation systems.

These are just a few of the technologies that until recently were viewed largely as ways of enhancing specialized farming operations. But they may have equal or even greater impacts on enhancing the potential productivity and profitability of low-input, diversified farming systems. All that is required is a change in the farming paradigm, a new model or way of thinking. With a new paradigm, diversified farming may be viewed as the system of the future rather than the system of the past.

Not only may existing technology be applied in new ways, but new technology may be forthcoming that will make possible even more sustainable and profitable farming systems in the future. Systems technology may follow once there has been a change in the farming paradigm.

Rising costs of specialized systems. There are several other logical reasons why farmers should question the advisability of continuing the trend toward greater reliance on external, purchased inputs, even if they view a return to diversified systems as going backward. First, there are growing indications of declining effectiveness of the technologies that allowed greater specialization. Insects are becoming resistant to insecticides, necessitating higher rates of application or new insecticides. New insects sometimes replace the old. Beneficial insects often are destroyed along with the pests, requiring even greater reliance on insecticides, at higher costs. The same types of problems are appearing for herbicides as new weeds appear after others are brought under control. In addition, herbicide build-up in some soils seems to be causing problems.

Some previously fertile soils have lost organic matter and natural fertility through monocropping or removal of aftermath year after year. Lower organic matter levels have meant less ability to hold water and nutrients in root zones, meaning lower yields from a given level of water and fertilization or higher fertilizer costs to maintain yields.

Other costs of increasing specialization are beginning to show up in the environment of farm families and workers. Health risks in handling pesticides have become a major issue in farm safety. These risks eventually translate into less effective pest control, higher labor costs, or greater health risks for family members.

Chemical contamination of farm water supplies is another emerging concern of farm families. This issue, as much as any other, has increased the awareness of farmers to the potential environmental hazards of chemically dependent farming. Until recently, the environmental costs of increased use of chemical fertilizers and pesticides were external to the farm or imposed on society in general. The health risks to farm families and workers are internal costs and thus command the immediate attention of farmers (*4*).

In short, current trends in fertilizer and pesticide use seem to point to an increasing cost of supporting specialized farming systems. Research currently is underway to validate or refute this hypothesis and, if valid, to evaluate its significance.

However, some farmers already have seen costs increase and productivity fall to the point where gains from specialization no longer offset increased costs. For them, lower input systems are also the most profitable systems.

Gains from integration: Synergism. Gains from specialization are undeniable, but specialization is not the only route to greater efficiency. There are potential gains also from integration. The productivity of an integrated system can be greater than the sum of the products of the individual system components. This phenomenon is called synergism (*8*). Specialized systems sacrifice the potential gains from synergistic interaction among the various components of diversified systems.

An obvious example of synergism is the interaction between livestock and crop rotations that include high quality legume forage crops. Livestock add value to the forage and recycle nutrients back to the soil in the form or manure. Legumes add nitrogen to the soil, break row-crop pest cycles, and provide feed for the livestock. Livestock without high-quality legume pastures may not be profitable. Legume rotations without livestock may not be profitable. However, integrated livestock, legume rotation systems may add profitability to the total farming operation. This is but one example of the potential synergistic gains from integrated farming systems.

Risk is another important but often overlooked consideration in diversification. Risks are far greater in a specialized farming operation than in a diversified farming system with the same basic level of uncertainty in each system component.

For example, assume that one farmer has four enterprises and that each has an equal chance of returning a positive $6,000 or negative $2,000 net return in any given year. Thus, if they all are positive, the farmer will make $24,000, and if they all are negative, he or she will lose $8,000. But let's assume that the enterprises are totally uncorrelated. Net returns from each enterprise move up or down independently of each other.

Now assume that another farmer specializes in one of the four enterprises but produces four times as much of it as our first farmer. The second farmer has the same chance of making $24,000 or losing $8,000 in any given year as the first has of making $6,000 or losing $2,000 on that one particular enterprise.

Both farmers have the same long-run average or expected net return, about $8,000. However, the diversified farmer is far more certain of a positive return than is the

specialized farmer. In fact, the variability of his net return from year to year will be only about one-half as great as for the specialized farmer in this case.

Risk-reducing effects of diversification are even greater if enterprise returns are correlated negatively, but will be less if they are positively correlated. Statistically calculated variance relationships between specialized and diversified operations vary from case to case. However, the general relationship holds: diversified systems yield more stable returns over time than do specialized systems. This is the foundation for the old saying, "Don't put all your eggs in one basket."

Many farmers are only beginning to recognize the wisdom of this old advice. The risk of specialization seemed acceptable to farmers when farm export markets boomed during the 1970s. But the risks became intolerable for many farmers during the farm crisis of the early 1980s. Most crop producers currently are shielded from those risks by a generous federal farm program. But more and more are asking if there isn't a better way—a way that will address the environmental questions surrounding modern agriculture and allow farmers to use the risk insurance provided by nature through more diversified farming systems.

The threat of regulation. Another reason for questioning greater reliance on external inputs is growing evidence of their external social or environmental costs. Environmental concerns have replaced farm profitability at the top of the political agenda for agriculture in Washington (*9*). This is a direct result of a growing awareness of the environmental impacts of an agriculture that depends upon chemical fertilizers and synthetic pesticides.

Nitrogen fertilizer and a select group of herbicides seem to represent the greatest agricultural threat to groundwater contamination. Soil erosion carries a wider range of potential chemical contaminants from farms into surface water supplies. Sedimentation of lakes and streams is still another significant external cost of specialized systems of continuous cropping.

Water quality has moved to the top of the research agenda. However, accurate assessments of negative environmental impacts and associated social costs may take several years (*1*). It seems doubtful that state and federal legislators will wait for a consensus on this issue before they act. Thus, farmers cannot afford to wait for regulation before they search for alternative farming systems.

Threats of regulation may be the primary motive for many farmers who have become interested in low-input, sustainable agricultural systems. Public policy provides a means to internalize costs that otherwise would be external and thus of no economic consequence to individual farmers. Costs of technologies that have allowed specialization may outweigh gains from specialization when all costs, private and social, are accounted for.

In fact, regulations may impose costs in excess of total social costs. This potential for overregulation provides an additional incentive for farmers to address environmental concerns voluntary. The threat of regulation provides a primary motive for farmers to ask whether or not they should reexamine the feasibility of low-input systems.

Sustainable profits, not profit maximization. Many farmers feel special responsibilities to society that go beyond those spelled out in government regulations. Farmers occupy most of the geographic area of the United States. They own most of the country, so to speak. Farmers also are responsible for providing food, clothing, and shelter for the people. People depend upon farmers for their very existence.

Society has given special consideration and concessions to farmers reflecting these critical relationships. Many farmers, in return, feel a moral obligation to fulfill their responsibilities and live up to this trust. This gives such farmers a set of values that cannot be captured in the dollar-and-cent language of most economic analyses.

Many farm families also place a high value on farming as a way of life. They may be willing to work harder for less money because they feel that the farm is a good place to live and to raise their children. They may value enterprises and activities that provide opportunities for family interactions and learning experiences in terms other than net returns.

But farmers cannot live on appreciation from society. And a desirable quality of life requires an acceptable level of income. A farming operation must be profitable or it cannot fulfill its social responsibility or be a good way of life for farm families.

Profitability is a necessary and, thus, important objective of any farming operation. However, profitability does not imply the same thing as profit maximization. Many farmers appear to be at least as concerned with other objectives as with profits. Such farmers, in growing numbers, support the alternative agricultural movement in U.S. agriculture.

Alternative agriculture includes farmers who identify with a wide range of concepts, including low-input, sustainable, regenerative, organic, holistic, agroecology, and others (*7*). All of these alternative agricultural concepts have one thing in common. They challenge the concept of profit maximization as the *dominant* factor in farm decision-making. Many farmers are challenging the wisdom of conventional farming systems because they challenge the motive of profit maximization, which has driven farmers to greater specialization.

Economic implications

Economists seem well prepared to deal with the macroeconomics of the social costs and social benefits associated with sustainable agricultural systems.[1] However, they seem less prepared to deal with the microeconomic, farm-level choices among conventional enterprises and sustainable farming systems. The microeconomics of sustainable agriculture call for a change of economic paradigms, but not a change in the basic principles of economics. We need new economic mind-sets or models but not new

SUSTAINABLE MUST BE PROFITABLE

As a nation, we are now centering much debate and rhetoric around "sustainable agriculture." As a society, we have been able to achieve a real mind set as to what sustainable agriculture is. Unfortunately, in my opinion, we immediately identify it as some sort of new and oftentimes exotic approach to the business of farming, such as growing Belgian endive, or other new and (to us) strange crops, often along the way ignoring markets, adaptability to our climate, and similar concerns.

While such factors as government farm programs, conservation concerns, and water quality are factors in sustainable agriculture, I feel we tend to miss the most important factor, namely, that sustainable agriculture, to be sustainable, must first and foremost be profitable.

Ultimately, profitable agriculture must remain the cornerstore of what we view as sustainable. Without profits, producers cannot continue in the business of agriculture. When we recognize this, we can then direct our efforts to deal with concerns about water quality and quantity, conservation, and appropriate use of chemicals in agriculture—issues that concern farmers as well as the public in general.

Farmers themselves are as important to the concept of sustainable agriculture as soil and water. The business of farming must be profitable for it to be sustainable.—***Bryce P. Neidig,*** *Nebraska Farm Bureau Federation, Lincoln.*

[1]Havlicek, Joseph, and Fredrick Hitzhusen. "Micro- and Macro-Economic Aspects of Sustainable Agriculture." Paper presented at the International Conference on Sustainable Agriculture Systems, Columbus, Ohio, September 1988.

economic principles to address the issue of sustainability.

Economics is the social science that deals with allocation of scarce resources among competing ends. Economics provides the principles for making choices that enable society and individuals to realize as much satisfaction as possible from limited resources. The basic assumptions of economics are that wants and needs are unlimited and that resources are scarce. We do not have sufficient resources to provide everyone with everything. We must make difficult choices.

The fundamental principles of economics are derived from the law of diminishing returns. As more and more of any good or service is consumed, at some point that good or service diminishes in its ability to provide added satisfaction. As more and more of any input is applied to a given, fixed resource base to produce something useful, at some point the input will diminish in its ability to add productivity.

Decisions based on sustainability are in no way inconsistent with these basic economic principles or with the fundamental laws on which economic principles are based. In fact, the issue of sustainability seems to be a perfect illustration of the relevance of economics to real world problems. How are scarce resources best used for the greatest benefit for individuals and society? This is the fundamental question of economics.

However, many conventional economic paradigms or models are based on economic assumptions that are not valid when dealing with issues of sustainability. Economists simply need to rethink their paradigms, not their fundamental laws. They need to go back to the basics.

Profit maximization. The assumption of profit maximization allows economists to develop models for optimum resource allocation. Profit maximization assumes that money can be converted into any good or service. Higher levels of net income or profit allow farmers to have more of everything or at least to have more of some things without giving up anything else. Thus, more profit will make farmers better off.

However, profits reflect only those costs and returns that are internal to the farm and thus are translated into dollars and cents. Social costs and benefits are not reflected in profits unless they are internalized through public policy.

External costs and returns, when included in economic analyses, are considered through a process of constrained maximization. Constrained maximization assumes that farmers maximize profits subject to individual constraints that might include maximum levels of soil loss, nonrenewable energy use, or environmental degradation. However, this paradigm implies that profit maximization is the dominant consideration.

Tradeoffs in productivity between external and internal inputs are critical in achieving a balance between profitability and sustainability.

Soil Conservation Service/Charles Rowson

Economists could just as easily assume that farmers minimize environmental degradation or maximize resource conservation subject to a profit constraint. Such a paradigm would seem more consistent with objectives of most farmers currently interested in alternative farming systems. Sustainable levels of profit may be viewed as a constraint to achieving environmental and social objectives. Considering profit as a constraint rather than the objective of decision-making is completely consistent with fundamental economic principles, but would be a new paradigm for most economists.

Managing for multiple objectives would seem to be a better model for those families who view farming as a way of life as well as a business and for those who choose to consider social costs and benefits in their private decisions. Managing for multiple objectives rather than maximizing profits is good economics and good common sense.

External inputs versus internal resources. Economists typically separate costs of production into fixed and variable categories. Fixed costs are associated with any resource or input that already is committed to the production process. Fixed costs will be the same regardless of how much, or even if nothing, is produced.

Variable costs are associated with those inputs not yet committed to production. Different quantities of variable inputs can be used, and the level chosen will affect costs of production and expected levels and production or output.

Economic analysis typically begins by assuming a given level of fixed costs associated with committed resources. The objective then becomes to choose the level of variable input that will maximize profits or net returns.

This paradigm has been used by economists to show that any deviation from profit-maximizing levels of purchased inputs, nitrogen fertilizer, for example, will represent a reduction in farm profits (*5*). This traditional paradigm ignores the possibility of generating productivity and profitability from internal resources as well as from external inputs.

Assume, for example, that 200 pounds of nitrogen is the profit-maximizing level of total nitrogen for a corn crop on a given field in a given year. This might indicate an addition of 180 pounds of nitrogen, assuming that 20 pounds of nitrogen are available from the soil. Traditional economic analysis would imply that any deviation from the 180 pounds of purchased nitrogen input would reduce profits.

This paradigm ignores the possibility of generating nitrogen through management of the soil resource rather than purchasing

nitrogen externally. Profits might instead be maximum with 130 pounds of purchased nitrogen per acre if 50 pounds of nitrogen could be generated at a lower cost internally, through the use of legumes, for example, than the cost of 50 pounds of nitrogen purchased in commercial fertilizer.

The paradigm of fixed and variable resources is not an inherent limitation of economic analysis. Economics provides the concepts and tools for dealing with changes in productivity of resources as well as inputs. The limitations are not in the economic principles but rather in the way those principles have been applied.

Resource risks—the cost of dependence. The concept of comparative advantage commonly is used by economists to illustrate potential gains from specialization and trade (*6*). The principles of comparative advantage show that maximum output can be achieved at minimum cost if all producers specialize in producing things they can produce most efficiently relative to other producers.

Specialized producers can trade their surplus production to others who have specialized in producing other things. Each producer trades with others to acquire the things they need and want but did not produce for themselves. By realizing comparative advantages, everybody could be better off without making anybody worse off.

Comparative advantage is a valid, useful concept. However, it ignores risks that are associated with real world economic decisions. In a perfect world, everyone would depend upon each other. In a perfect world, we would have perfect information about the present and the future. In the real world, however, we have learned that we cannot always depend upon others for our own well being, and we face uncertainty concerning both the present and the future.

Few countries are willing to depend totally on any other country for its survival. Countries sacrifice potential gains from specialization and free trade to maintain some minimum level of economic security. Few regions, states, or communities within countries seem comfortable with employment bases that rely on markets or input suppliers in places beyond their economic control or influence.

Countries, regions, and communities recognize the necessity to specialize as a means of realizing their comparative advantages. The costs of self-sufficiency are too high. However, they also are willing to sacrifice some level of economic gain from specialization to maintain a degree of economic or social independence.

Farmers who rely on external inputs and specialized farming systems for their economic well-being are similar in many respects to countries, regions, and communities that rely on specialization and trade for their economic well-being. They gain from greater economic efficiency by realizing their competitive advantages relative to other economic entities.

However, reliance on external markets and inputs embodies risks—risk that currently profitable markets will be lost and risk that inputs will no longer be available at reasonable costs from external sources.

Perhaps the most graphic, recent example of such risks was the reliance of U.S. crop producers on export markets for wheat, corn, and soybeans during the 1970s. Many farmers borrowed large sums of money to buy additional land and buy specialized equipment to supply these potentially profitable markets.

Specialized farmers producing export commodities were hardest hit by the financial crisis of American agriculture in the early 1980s. They had taken the risks associated with dependence on external inputs, including capital and labor-saving equipment in addition to chemical fertilizers and synthetic pesticides, to produce for markets that were vulnerable to an unpredictable world economy.

Farmers today who rely heavily on synthetic chemical pesticides and fertilizers must consider the risk of future restrictions on use of those inputs. Such restrictions may make some inputs unavailable and others more costly. Economists have developed well-defined concepts and tools for evaluating financial risks associated with reliance on borrowed capital. Financial risks are a specialized case of the more general concept of resource risks.

The economic principles of decision-making under uncertainty and risk are adequate to address the issue of resource risks associated with various levels of reliance on purchased inputs versus internal resources. However, those principles are yet to be applied to the question of low-input, sustainable agricultural systems.

The key: Tradeoffs

Tradeoffs are the key to decision-making, the key to evaluating the sustainability of farming systems. Systems must be chosen that consider tradeoffs between resource conservation and environmental soundness on the one hand and productivity and competitiveness on the other. In many cases, this will mean considering tradeoffs between long-run sustainability on the one hand and greater short-run profitability on the other.

Tradeoffs between productivity from external inputs and productivity from internal resources are critical in achieving an acceptable balance between short-run profitability and sustainability. Productivity from internal resources is the result of synergism achieved through integrated farming systems. Productivity from external inputs often reflects gains from specialization. Tradeoffs between gains from specialization and gains from integration are critical in developing systems that are both profitable and sustainable.

Tradeoffs between comparative advantage and resource risks are another critical consideration in balancing short-run profitability with long-run survival. Systems that are most profitable in the short run may be most vulnerable in the long run.

Economics is the science of tradeoffs. Economics is sometimes called the dismal science because it points to the tradeoffs of potential cost and potential benefit associated with each decision alternative. However, economics is reality. There are potential costs associated with each potential benefit in all cases of significant choice. There are potential losses in short-run profitability that must be weighed against the benefits of long-run sustainability.

Better decisions rarely result from systematically ignoring reality. Economics has a vital contribution of make to low-input, sustainable agriculture. Economists must be willing to change their paradigms to address the relevant issues. Low-input, sustainable agriculture advocates must be willing to accept economic reality.

REFERENCES CITED

1. Council for Agricultural Science and Technology. 1988. *Long term viability of U.S. agriculture.* Rpt. No. 114. Ames, Iowa.
2. Dobbs, Thomas, Mark Leddy, and James Smolik. 1988. *Factors influencing the economic potential for alternative farming systems: Case analysis in South Dakota.* Am. J. Alternative Agr. 3(1): 26-34.
3. Edwards, Clive. 1990. *The importance of integration in sustainable agricultural systems.* In Clive Edwards, Rattan Lal, Patrick Madden, Robert H. Miller, and Gar House [eds.] *Sustainable Agricultural Systems.* Soil and Water Cons. Soc., Ankeny, Iowa. pp. 249-264.
4. Francis, Charles. 1988. *Sustainable versus non-sustainable resources: Options for tomorrow's agriculture.* Nat. Forum: Phi Kappa Phi. J. LXVII (3): 7-9.
5. Holt, Don. 1988. *Agricultural production systems research.* Nat. Forum: Phi Kappa Phi J. LXVII (3): 14-18.
6. Ikerd, John E., Bob Glover, Joe Purcell, Jim Cornelius, Keith Scearce, and Par Rosson. 1988. *Finding competitive advantages in agriculture.* Ext. Serv., Univ. Ga., Athens.
7. Macher, Ron. 1989. *Agroecology: What's it all about?* Missouri Farm (January-February): 37-37.
8. McNaughton, Noel. 1988. *Sustainable agriculture: Farming that lasts.* Univ. Alta. Agr. and Forestry Bull. 11:4.
9. Myers, Peter C. 1988. *Agriculture and the environment.* Soil and Water Cons. News (July): 5.
10. Rodale, Robert. 1988. *Agricultural systems: The importance of sustainability.* Nat. Forum: Phi Kappa Phi J. LXVII (3): 2-6. □

Policy proposals to foster sustainable agriculture

By Chuck Hassebrook and Ron Kroese

Extension Service

SUSTAINABLE agriculture is changing American agriculture, in spite of public policies hostile to the farmers who practice it. Until recently, sustainable agriculture was shunned by most of the agricultural research establishment. Even today, the U.S. Department of Agriculture's low-input/sustainable agricultural (LISA) research program accounts for less than one-half of one percent of the federal investment in agricultural research and extension. Federal farm commodity programs penalize sustainable agriculture. Midwestern farmers who use low-input crop rotations have smaller corn acreage bases and consequently forego as much as two-thirds of the deficiency payments received by continuous corn producers. Finally, low-input, sustainable farmers whose crop rotations enhance soil tilth and thereby reduce soil erosion do not get adequate credit under the universal soil loss equation (USLE) and conservation compliance. If they farm erodible soils, they are likely to be encouraged by the local office of the Soil Conservation Service (SCS) to switch to chemical-intensive systems, such as no-till, continuous corn and drilled soybeans.

Farm bill goals and proposals

The 1990 farm bill presents the opportunity to change public policy to facilitate the development of low-input, sustainable farming systems and reward farmers who practice stewardship in the broadest sense. To accomplish that, we must begin by clearly defining and articulating a set of goals for agriculture that encompass sustainability of farm communities, the resource base, and food supplies.

Specifically, we believe that the farm bill should aim to achieve the following goals and purposes:

► *Maximize the number of opportunities for self-employment in agriculture and rural communities and foster a more equitable economic and social structure.* A substantial body of sociological research indicates that a dispersed farm structure, with many owner-operated farms, creates healthier communities than a large farm structure. A University of California researcher summarizes these findings as follows: "As farm size and absentee ownership increase, social conditions in the local community deteriorate. We have found depressed median family incomes, high levels of poverty, low education levels, social and economic inequality between ethnic groups, etc., associated with land and capital concentration in agriculture. Communities that are surrounded by farms that are larger than can be operated by a family unit have a bi-modal income distribution with a few wealthy elites, a majority of poor laborers, and virtually no middle class. The absence of a middle class at the community level has a serious negative effect on both the quality and quantity of social and commercial services, public education, local governments, etc." (*14*).

► *Prevent environmental contamination and resource depletion.* More than 170 million acres of U.S. farmland are eroding at rates that threaten its long-term productivity, endangering food security and contaminating surface waters (*16*). (This data predates implementation of the Conservation Reserve Program and may be overstated by about 34 million acres.) A 1985 U.S. Geological Survey study revealed that 20 percent of the nation's wells are contaminated by nitrogen fertilizers (*15*). More than 25 percent of Iowa's population is using drinking water that contains pesticide residues (*8*). To date, the U.S. Environmental Protection Agency (EPA) has found 74 pesticides in the groundwater of 38 states (*18*).

► *Enhance human health.* While much attention has been focused recently on issues of food safety, growing evidence of the impact of modern farming practices on the health of farmers has received relatively little attention. Numerous epidemiological studies have shown a strong correlation between various types of cancer, especially leukemias, and farming or living in agricultural areas (*16*). Studies by the National Cancer Institute and the University of Kansas indicate that farmers exposed to herbicides for more than 20 days each year are several times more likely than nonfarmers to develop cancerous tumors known as non-Hodgkins lymphomas (*10*).

► *Enhance the resiliency of our food and fiber system.* Of particular concern are the impacts of resource depletion, environmental disruption, and dependence on nonrenewable resources on long-term food security. "U.S. oil production is poised on the edge of a sharp drop off" and with that drop off,

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the U.S. "may be unable to export food much beyond the year 2,000" (*7*). Likewise, U.S. agriculture is vulnerable to potential rainfall reductions associated with global warming. Although the impact of global warming on rainfall patterns is uncertain, some climatologists predict that the greenhouse effect will shift rainfall north and east away from the nation's best soils, moving unirrigated corn production out of most of Illinois, Iowa, Kansas, Missouri, Nebraska, and the Dakotas in 50 years (*6*).

► *Enhance the efficiency and profitability of America agriculture as we address social and environmental concerns.*

Can the farm bill advance each of these goals simultaneously? We believe that it can if fundamental changes take place in both current public policies and the way we approach farming systems.

Research policy recommendations

Agricultural research is, in effect, a form of social planning. Choices made by Congress, research institutions, and researchers about what research is undertaken in part determine what farming systems, varieties, and technologies are developed, become cost-effective, and are put to use. These technologies, in turn, profoundly shape economic and social structures, the natural environment, and human health. If a just society and healthy environment are to be achieved, these decisions must be made with consideration of broad social and environmental goals.

The highest priority for the research title of the 1990 farm bill should be articulation of the goals and purposes that underlie the federal investment in agricultural research, including the federal dollars that go into formula funds, competitive grants, and other federal agricultural research funds. Those goals and purposes should include those presented earlier for the structure of agriculture, human health, farm resiliency, and the environment. Procedures should be defined by Congress to ensure that these goals and purposes are considered and reflected in setting research priorities.

These procedures should include preparation of technology assessments of the range of likely social and environmental impacts of alternative research programs for use in the priority-setting process. In addition, the secretary of agriculture should annually approve or disapprove the plan of each land grant institution for use of federal formula research and extension funds, based on whether that research will have the net effect of advancing the goals and purposes established by Congress.

It is particularly important that such goals and purposes be defined for any major increase in federal funding for agricultural research. Much of the agricultural research community, with leadership being provided by the Board on Agriculture of the National Academy of Science and the major land grant universities, are uniting in support of a proposal to increase federal funding of competitive grants for agricultural research by $500 million per year. If such an increase is authorized and appropriated, a portion of the research funds should be specifically earmarked for assessing the likely impacts of alternative research directions. In addition, requests for proposals should list areas of research that are promising in advancing the goals articulated. Criteria for judging proposals should be designed to reward research that enhances economic opportunity, the environment, human health, and resiliency as well as efficiency.

Are these conflicting goals?

Farming systems research aimed at developing an understanding of natural systems to enable farmers to adjust their management practices to work in concert with nature, that is, to reduce pests, lower petrochemical use, conserve soil, and protect the environment, can be shaped to simultaneously enhance efficiency and family farm opportunity. To do so, researchers must seek efficiency by enhancing the role of people in agriculture and making it possible to reduce capital expenditures and input use through more intensive application of skilled labor and hands-on management. Whereas past research sought to reduce costs by replacing two dollars worth of time with one dollar worth of inputs, researchers would instead seek to improve efficiency by replacing two dollars worth of inputs with one dollar worth of time. Systems that rely on sophisticated and highly motivated labor able to exercise judgment in the field and barn would be better suited to an owner-operator structure than to an industrial system in which most labor is provided by unskilled and poorly paid employees.

This is not to say that public funds should never support research that addresses large-scale agriculture. It is appropriate to do research aimed at developing better management practices that reduce environmental problems associated with large-scale agriculture. However, if increased opportunity for family farmers is an important social goal, it would be counter-productive to invest limited public resources in research to make large-scale agriculture more competitive. Rather, the bulk of agricultural research should focus on developing farming systems that simultaneously enhance economic opportunity, efficiency, and environmental quality.

Priority research and extension

The following areas of research and extension would advance these goals:

► *Agroecology research.* As Texas A&M University Plant Pathologist J. A. Browning says, "There is a great dearth of research from an 'agroecosystem approach,' which would enable farmers to choose, from among the many interacting cropping systems and farming practices, those that work together to produce the desired result" (*1*). This would enable farmers to develop management systems that reduce input use and maintain yield.

► *Nutrient cycling.* This would include research on nutrient cycling and management in low-input systems, as affected by farming practices and environmental conditions.

► *Research on developing crop varieties and livestock of potential value in addressing pests and other constraints that cannot be economically controlled by changes in farming practices.* Development of corn resistant to rootworms, generally controlled by crop rotation, should be of a lower priority than research on resistance to corn borers and diseases not easily controlled by cultural practices. Research should address the range of crops valuable in sustainable systems, rather such major crops as corn, soybeans, wheat, and cotton.

► *Research on farming in an uncertain climate.* While predictions of reduced rainfall from climatic change are uncertain, it would be wise to step up research to prepare for that possibility, including breeding more drought tolerant plants; developing management systems to maximize populations of beneficial mycorrhizae fungi; and developing management practices to reduce evaporation, lower crop water use, and increase water absorption, including rotations, tillage systems, windbreaks, organic matter management, and cover crops.

► *Research on soil-building crops.* Research is needed to develop new uses for soil-building tree, forage, and rotation crops and new crops that reduce soil erosion and reliance on petrochemicals and other purchased inputs.

► *Research to develop moderate-investment livestock production systems that reduce capital barriers to small and beginning farmers and allow them to earn a return on their skilled labor and intensive management that such systems require.* Disease and breeding research would focus on overcoming the stresses in such systems, including parasites and temperature variation.

Total confinement livestock systems have contributed to the severe decline of meat and milk production on moderate-sized, owner-operated farms. The high investment costs preclude moderate-scale application; the repetitive labor and management tasks in these systems is then conducive to operation by unskilled labor. For example, it costs twice as much per cow to build confinement facilities for a 52-cow dairy as for a 600-cow dairy (*3*). Moderate-investment facilities are a better alternative to family-scale producers seeking to minimize production costs. In spite of the research emphasis on total confinement systems over the last 20 years, a University of Tennessee study found that hogs could be produced more cheaply in a moderate-investment, farrow-to-finish system than in a high-investment, total confinement system (*12*).

Research on moderate-investment livestock production systems should include efforts to improve the nutritional content of the crops grown on diversified farms to reduce the need for feed supplement purchases. This would reduce the significance of the economic disadvantage smaller farms face in buying feed supplements. Small hog producers pay much more for their feed supplements than larger producers (*19*).

► *Extension programs specifically designed to reach small- and moderate-sized farmers, including potential beginning farmers and minority farmers who might otherwise be left behind by rapidly changing technology.* We are entering the era of information-intensive agriculture, as we make greater use of biotechnology and low-input, sustainable systems. Whereas in recent years those who lacked capital were left behind, in coming years those who lack information will be left behind (*9*). If society wants to protect a base of small farm operators, it may be necessary to undertake a major extension effort to develop their management capabilities (*13*). The content of the program should include a major focus on low-input and low-investment systems appropriate to farmers with limited capital. The program should include procedures for identifying research needs of participating farmers and feeding those needs into the land grant research priority-setting process.

► *Innovative extension programs.* Such programs are needed to engage the public in the debate over the future of the food and agricultural system and involve them in setting agricultural research priorities.

Finally, funding for the LISA program should be increased to $50 million per year, from its current $4.45 million. In spite of being woefully underfunded, this program has been successful in stimulating a substantial amount of research with potential for developing a more economically, environmentally, and socially sound agriculture.

Farm program recommendations

Just as research priorities tend to set social policy, federal commodity programs in large measure determine what crops farmers will produce. With regard to sustainable agriculture, USDA's income protection programs discourage the broader adoption of less chemically intensive approaches to farming, often forcing producers committed to more sustainable methods to sacrifice economically in order to farm in a manner consistent with their environmental values.

Many farm-level studies comparing low-purchased input, sustainable farming systems with conventional systems have demonstrated the efficacy of sustainable agriculture. Institutional and on-farm research projects during the past two decades have shown that sustainable farming practices can eliminate or reduce the use of petrochemicals with only modest, if any, yield reductions. These studies also have shown reduced production costs, increased net returns, and improved energy efficiency (*2*). Other macroeconomic and social benefits cited in reviews of organic and low-input farming include decreased soil loss and runoff, reduced depletion of fossil fuels, improved fish and wildlife habitat, and protection of soil productivity and water quality for future generations (*4*).

The recent report on sustainable or, as the study calls them, "alternative" agricultural approaches by a committee of the National Research Council's Board on Agriculture confirms those findings, stating in its executive summary: "The committee's review of available literature and commissioned case studies illustrates that alternative systems can be successful in regions with different climatic, ecological, and economic conditions and on farms producing a variety of crops and livestock. Further, a small number of farmers using alternative systems profitably produce most major commodities, usually at competitive prices, and often without participating in federal commodity and income support programs" (*5*).

The study goes on to point out the enormity of the influence commodity program rules have on agriculture practices, noting that the provisions governing allowable uses of base acres promote specialization in one or two crops and that between 80 and 95 percent of all acreage producing corn, other feed grains, wheat, cotton, and rice currently are enrolled in federal commodity programs. The study concludes:

"Many federal policies discourage adoption of alternative practices and systems by economically penalizing those who adopt rotations, apply certain soil conservation systems, or attempt to reduce pesticide applications. Federal programs often tolerate and sometimes encourage unrealistically high yield goals, inefficient fertilizer and pesticide use, and unsustainable use of land and water. Many farmers in these programs manage their farms to maximize present and future program benefits, sometimes at the expense of environmental quality" (*5*).

Clearly there is wide agreement that federal commodity programs must change if the United States is to attain a low-input, sustainable, family farm-based agricultural system. Proposals range from calls for demand-based, supply management with loan rates approaching parity, to decoupling farm income support from production altogether, to a variety of suggestions that to various degrees adjust and amend current programs. All of the proposals are motivated by the further goal of reducing the amount of money paid out annually to producers through the federal Commodity Credit Corporation, which in 1987 and 1988 amounted to $34 billion.

While it is clear that farmers need to be given flexibility in their production decisions, we do not join those who advocate eliminating farm programs or decoupling payments from farm production and practices. The free market does not reward stewardship of natural resources. Further, decoupling would sever the vital link of accountability between the American taxpayer and the nation's food production system—a foolhardy move toward domestic insecurity in a nation where all of us who eat are dependent upon the three percent who are food producers. Rather, we believe that farmers should be supported for successful farming, for "meeting the expectations of the land," as geneticist/ecologist Wes Jackson has said. Commodity programs should stimulate farmers to practice careful stewardship by diversifying crops and livestock, rotating crops, and greatly reducing the use of toxic chemicals. Program benefits should be targeted to family-sized farmers who demonstrate through their farming methods a commitment to this type of stewardship.

The following policy changes are recommended to help move agriculture in this direction:

► *Base and payment protection should be extended to all farmers who use environmentally sound crop rotations.* Farmers should be encouraged to plant up to 40 percent of farm program base acres to a resource-conserving legume or legume/small grain mixture as part of a soil-conserving, water-protecting crop rotation, while retaining the base and receiving the same deficiency pay-

ment as he or she would have received for planting the program crop.

► *The acres on which a farmer can receive payments should be capped at 66 to 80 percent of planted acres to reduce the current incentive to produce only program crops.* Money saved could be used to boost payments to farmers employing sustainable practices. Under the current program, a farmer producing continuous corn receives three times the farm program benefits as a farmer using a more sustainable corn-soybean-oat/clover rotation.

► *In the long term, base acres for farms should be fundamentally redetermined, not according to cropping history, but according to the suitability of the land to grow the respective program crops.* Bases would be limited to the extent and types of cropping that do not degrade the long-term productivity of the soil or contaminate water. With the highly accurate mapping of soils now completed in much of the country and the increased information available regarding areas particularly vulnerable to groundwater degradation, such an approach based on the suitability of the land is possible, but it would no doubt take several years to put into place.

► *In addition, payment yields used in calculating program benefits should be set according to the inherent productivity of the land rather than proven yields.* Such a system would remove the incentive for producers to fertilize heavily to increase farm program benefits.

► *To more effectively and consistently direct farm program benefits to family-sized farms, a two-tiered target price system should be established with a limit placed on the volume of production supported at the higher rate.* Deficiency payments, the amount paid by USDA to producers to compensate for low market prices, should be based on the higher target price on no more than $80,000 to $100,000 worth of program commodities. In effect, that would mean that under current price levels government payments at the full rate would be limited to 30,000 to 36,000 bushels of corn or 20,000 to 25,000 bushels of wheat. Eligibility for the higher target price should be phased out as the nonfarm income of an eligible producer exceeds the national median income or as the total income (farm and nonfarm) exceeds twice the national median income.

Larger producers and farmers exceeding the income limits would receive payments at a lower level. In effect, this lower tier would reimburse farmers for participating in supply control and conservation programs while the higher tier would provide additional income support for moderate-sized, moderate-income farmers who depend on the farm for their livelihood.

► *USDA should establish a program of multiyear set-aside contracts for a minimum period of three years to further bring production under control in an environmentally responsible manner.* At least 20 percent of the land taken out of production each year should be included in such multiyear contracts. Any highly erodible land included in multiyear contracts should be established in permanent cover. All other land included in any set-aside or diversion programs, including annual set-asides, should be required to be rotated and sown in a soil-building legume crop to provide full-year protection, with up to 20 percent reserved for wildlife habitat. Cost-share funds should be provided to compensate farmers for costs of establishing vegetative cover.

► *A low-input, sustainable agriculture program should be implemented to reward farmers who use sustainable farming systems and encourage others to move in that direction.* Legislation introduced last year by Senator Wyche Fowler (D-Ga.) and Representative Jim Jontz (D-In.) would create such a program. Farmers, with the help of their county SCS and Extension Service offices, would develop five-year, farm-specific plans, which, by the end of the period, would limit chemical use to low levels and hold soil erosion to rates that do not threaten long-term soil productivity. Under the program, participants' yield histories could not be adjusted downward during the five-year transition period. If implementation of the low-input plan resulted in lower total production, the farmer's acreage set-aside requirement would be reduced. Deficiency payments would be made on the base acres devoted to resource-conserving crops, such as small grain/legume mixtures, just as if they had been planted to the program crops. For farmers with low bases due to historic use of low-input, sustainable rotations, the Jontz proposal would increase crop bases for purposes of receiving these payments. The Fowler version would preserve 1989 target prices for five years for participants.

Other policy recommendations

SCS should incorporate low-input, sustainable agricultural approaches into its technical assistance programs and adopt means of measuring erosion that account for the full erosion control benefits of low-input rotations. The USLE does not consider the effects of crop rotations on soil organic matter and soil structure and subsequent effects on water infiltration. Consequently, it does not account for the full erosion control benefits of diverse rotations, especially those including cover crops and forages. The USLE, therefore, may overestimate erosion on many farms using low-input rotations (*11*).

This bias in the means of measuring soil erosion has contributed to an emphasis in SCS technical assistance on chemical-intensive cropping systems, such as no-till, continuous corn, which may be misguided. Greater net environmental benefits may well be found, particularly when taking into account groundwater quality, by encouraging adoption of low-input cropping systems designed to enhance soil structure and organic matter levels. USDA's water erosion prediction project is developing a new erosion prediction model to replace the USLE. This model should be designed to measure the full erosion control benefits of such systems.

REFERENCES CITED

1. Browning, J. A. 1985. *Plant disease and nematode control.* Off. Tech. Assess., U.S. Cong., Washington, D.C.
2. Buttel, F. H., G. W. Gillespie, Jr., R. Janke, B. Caldwell, and M. Sarrantonio. 1986. *Reduced-input agricultural systems: Rationale and prospects.* Am. J. Alternative Agr. 1: 58-64.
3. Buxton, Boyd M. 1985. *Economic, policy, and technology factors affecting herd size and regional location of U.S. milk production.* Off. Tech. Assess., U.S. Cong., Washington, D.C.
4. Cacek, T., and L. L. Langner. 1986. *The economic implications of organic farming.* Am. J. Alternative Agr. 1: 25-29.
5. Committee on the Role of Alternative Farming Methods in Modern Production Agriculture. 1989. *Executive summary.* In *Alternative Agriculture.* Nat. Acad. Press, Washington, D.C.
6. Decker, Wayne L. 1985. *The implications of climate change for 21st century agriculture.* In *The Farm and Food System in Transition: Emerging Policy Issues.* Ext. Serv., U.S. Dept. Agr., Washington, D.C.
7. Gever, John, et al. 1986. *Beyond oil.* Ballinger Publ. Co., Cambridge, Mass.
8. Hallberg, George. 1986. *From hoes to herbicides: Agriculture and groundwater quality.* J. Soil and Water Cons. 41(6): 356-364.
9. Harshbarger, C. Edward. 1987. *Financial survival in an era of technological change.* J. Agribus. (February): 37-40.
10. Hoar, S. K., et al. 1986. *Agricultural herbicide use and risk of lymphoma and soft tissue sarcoma.* J. Am. Medical Assoc. 256: 1,141-1,147.
11. Jackson, Mary. 1988. *Amish agriculture and no-till: The hazards of applying the USLE to unusual farms.* J. Soil and Water Cons. 43(6): 483-486.
12. Johnston, Gene. 1984. *Mid-cost hog system shows most profit.* Successful Farming (November): 116-117.
13. Kliebenstein, James, and Y. Shin Seung. 1987. *Impact of BST on dairy producers.* Dept. Econ., Iowa State Univ., Ames.
14. MacCannell, Dean. 1983. *Agribusiness and the small community.* Off. Tech. Assess., U.S. Cong., Washington, D.C.
15. Madison, R. J., and Jilann Brunett. 1985. *Overview of the occurrence of nitrate in groundwater of the U.S.* Water Qual. Paper 2275. U.S. Geol. Surv., Reston, Va.
16. Strange, Marty, Liz Krupicka, and Dan Looker. 1984. *The hidden health effects of pesticides.* In *It's Not all Sunshine and Fresh Air.* Center for Rural Affairs, Walthill, Nebr.
17. U.S. Department of Agriculture. 1987. *The second RCA appraisal.* Washington, D.C.
18. U.S. Environmental Protection Agency. 1988. *Pesticides in ground water data base.* Washington, D.C.
19. Van Arsdall, Roy N., and Kenneth E. Nelson. 1985. *Economics of size in hog production.* Tech. Bull. No. 1712. Econ. Res. Serv., U.S. Dept. Agr., Washington, D.C. □

Social traps and incentives: Implications for low-input, sustainable agriculture

By Jeffery R. Williams

RECENT attention concerning low-input, sustainable agriculture systems brings to the forefront concern that conventional agricultural production methods result in a "social trap." The term refers to situations in which an individual or society starts in a direction or relationship that later proves to be unpleasant or lethal, with no easy way to change or avoid the situation (*7, 10, 11*). A social trap typically occurs when conflicts exist between highly motivating, short-run rewards and long-run consequences.[1] A social trap also occurs when a personal reward or punishment conflicts with a group's goals. In this case an individual acts for his or her personal gain and in the process prevents the group from obtaining a reward or objective. In designing public policy to encourage sustainable agriculture, a major consideration is the tendency of individual behavior to be motivated more by immediate personal gain than by the long-run public interest—which leads to a social trap.

Current agricultural production methods may lead to social-trap problems. Producers use fertilizers and pesticides to increase short-run production levels and profits, with encouragement by current agricultural policies that attempt to maintain low food prices and high farm incomes. In the long run, however, these production techniques and policies may result in externalities for other producers and the consumer, including chemical residues on food products, nitrate contamination of water supplies, and toxic chemical exposure. The immediate personal goal or self-interest that leads to the use of purchased inputs to produce greater profits can result in detrimental, long-run personal and societal outcomes.

Although public support for agriculture is still prevalent, it is eroding as the impacts of agricultural practices and policies on farm employment, the environment, the structure of agriculture, and rural communities are increasingly perceived as negative and severe

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Soil Conservation Service/Tim McCabe

(*2*). Agricultural producers are caught in a social trap because of the incentives they receive for current production practices.

Adoption of low-input, sustainable systems is enticing because of the potential reduction of externalities or negative consequences of the social traps on society. A question often raised at public meetings and in the popular press is this: How do we get farmers to adopt low-input, sustainable systems? Often, the immediate answers given are either voluntary use through education or direct government regulation. But implementation of low-input systems could be encouraged by breaking the current social traps. How are social traps changed?

[1]Use of addictive, illegal drugs can serve as an example of a social trap that has negative implications for the drug user and for society. In some cases, a biochemical reinforcement, or a "good" feeling, arises from drug use, which leads to addiction. There also may be social reinforcement from the individual's peer group in the short run. Long-run negative consequences, however, include poor psychological and physical health for the individual and a number of related consequences for society, including increased crime, higher health insurance costs, lower productivity, and decreased safety.

Low-input's social trap

A problem of this nature usually cannot be solved by a few volunteers, although this solution is often suggested. The problem is not the result of a single person or small groups acting unethically. Even if individuals act differently to reduce the long-term consequences of their actions, the outcome will not change significantly without collective action by a critical number of the resource users (*7*). Many tend to see externality problems created by agriculture as problems with information or education. Some suggest that if farmers are educated on how to reduce environmental externalities caused by their current production practices, they will act accordingly.

Although education about technological solutions is important to change production practices, financial incentives provided by public policies also are needed. Abdalla and Libby (*1*) discuss the need for this approach. The current "rules of the game" have incentives (reinforcement for current practices) that contribute greatly to current production methods in spite of externalities created for society. Because of individual micro-motives and existing incentives, we cannot assume that producers will take action even if they are educated about the problem and how to deal with it. Individual producers may view the current situation in any of the following ways:

► Most individuals believe that each person's impact is small with regard to the overall problem, and consequently, the contribution they can make toward solving it is also small, particularly in relationship to the potential cost of contributing.

► An individual's cost of changing production practices may be large, and the individual's contribution to the public benefit will go to all, including those who do not contribute.

► Individuals are uncertain that they will be rewarded with any personal benefit from the action they take, because of the lack of action taken by others and a poor understanding of the actual environmental benefit.

► Individuals who take no action also may benefit because of others' actions, with no expense to themselves.

For these reasons, the number of volunteers needed to achieve the desired results may not be achieved, and the few who do volunteer (those who may agree with the purpose regardless of the cost to themselves and the resulting benefit) will have little impact. These types of group problems have been discussed by Olson (*9*) and by Schmid (*11*).

Breaking the social trap

The solution to breaking the social trap is to change the reinforcement mechanism. Incentives can change the reinforcement relationship in a social trap. They play a large role in reinforcing current practices of individuals; therefore, a set of different incentives can play a large role in changing the practices of producers. Policy mechanisms have to be developed to make environmental goals financially viable and part of producers' economic decision-making.

There is a widespread belief that low-input, sustainable agricultural systems, at least in the immediate future, will be unprofitable and risky. In addition, educational information has been geared largely to practices using purchased inputs. Recent attention has been given to the impact of cultivation practices on soil conservation. Soil conservation, however, is only one aspect of the sustainability issue. Farmers may be concerned about adequate support and knowledge, through traditional channels, for dealing with low-input, sustainable management problems (a problem not unlike the early adopters of farm computers experienced). Although low-input, sustainable systems may yield immediate benefits, such as the risk-reducing effects of diversifying with rotations, farmers run the institutional risk of violating provisions of the government commodity program and losing eligibility for government payments. Therefore, rewards to encourage changes in current production practices are needed to get out of the social trap.

Financial incentives could be used as a reward for adopting or encouraging low-input, sustainable systems. For example, cost-sharing and tax credits to establish new practices could be used to encourage the reduced use of specified chemicals. Tax credits, which result in increased after-tax income, could be used to encourage farmers to attend training sessions and adopt low-input techniques. Government commodity programs could be reformulated to include production practice guidelines for eligibility.

Purchased chemicals and fertilizers also could be taxed as an incentive to reduce their use and to encourage increased efficiency in their use. Shortle and Dunn (*12*) indicate that appropriately specified management practice incentives, for example, taxes or subsidies, should generally be superior to standards. Less use of chemicals would likely lead to less production and a reduction in surplus commodities. Because of the inelastic demand for food, commodity prices then will rise with the decline in production and may lead to higher net farm revenues even though production is reduced. As a result of lower levels of input use, fewer pollutants are delivered to the environment. Also, federal farm commodity program costs would likely be reduced.

Of course, the response to a tax would depend on the elasticity of demand for purchased inputs, as well as input price changes. A tax might have to be extremely high to offset the possibility of increased returns because of higher prices. Agrichemical use and profit-maximizing behavior have been discussed in detail (*3*).

Some sectors of the economy would experience undesirable impacts. Food costs as well as feed costs for livestock would rise. The volume of manufactured inputs, transported inputs, and employment in related input industries would likely decline. Export markets also may be adversely affected.

Chemical use can be characterized as excessive for several reasons, according to Daberkow and Reichelderfer (*3*); the principal reason is this: "Externalities arising from agrichemical use imply that privately determined optimal rates of use are higher than their corresponding social optima. Underground and surface water quality, food residues, human health, and farmworker safety are the common externalities associated with agrichemicals. Failure to incorporate these negative-valued outputs underprices agrichemicals." By imposing a tax on the use of such chemicals, a higher cost per unit can be brought to bear on the user and thus encourage lower levels of chemical usage. The effect is to change the delay in the social trap situation. A tax converts long-range consequences for society into immediate consequences (higher costs) for the producer who creates the externalities.

A tax, however, would not be easy to implement. Research would be required to determine the level of tax needed to change producer behavior. If the demand for chemicals is quite unresponsive to price, large taxes may be necessary to change farmer behavior. Implementation of the proper levels for a wide variety of inputs may prove difficult. Other programs, such as education, subsidies, tax credits, and cost-sharing, would likely be needed to encourage alternative practices.

Incentive-based approach

A charge system imposing additional fees and taxes on chemical inputs using a market-based incentive approach, as well as incentive payments for adopting alternative practices, may be preferable to a regulated solution that enforces specific farming practices or bans specific chemicals. Costs of developing and disseminating information and administering and enforcing a mandated technological solution may be large in comparison, although enforcement and information systems to monitor the result will be necessary under any alternative.

Madden (*8*) suggests that low-input, sustainable methods would be highly site-specific. Therefore, it would be difficult to dictate the techniques to use for reducing environmental externalities through regulation. Farmers would be affected differently. Incentive-based systems would allow the entrepreneurs to decide how best to adjust farm production to obtain a higher level of environmental quality, given strong financial incentive to do so. A cost imposed on a pollution-causing activity and a reward to adopt alternative practices, instead of regulations to change action, would provide incentives for change. Although regulation is important and should not be ruled out, incentives should be allowed to play a role when applicable. A technical discussion of standards versus incentives is provided by others (*5, 12*). Nontechnical discussions of subsidies, taxes, and standards also are available (*4, 6*).

Attention must be given to conflicting incentives as well. To a large extent, current government program restrictions prevent the construction of alternative sustainable rotations, including legumes. The restrictions use crop yields and base acre figures from historical production. Only certain types of crops are eligible for deficiency payments. A more detailed discussion of how the commodity program encourages conventional agricultural practices is provided by Young (*13*). Crop insurance requirements are also an impediment because they specify that producers must use generally accepted production practices. Although the Conservation Title of the 1985 Food Security Act establishes some incentives for soil conservation, many of the resulting management strategies for conservation compliance require greater use of chemicals for weed and pest control. Therefore, new incentives can-

not be established without examining the incentives inherent in current agricultural policy that create the social traps we wish to avoid.

The task ahead

The agricultural community not only has the difficult task of defining and identifying low-input, sustainable systems but also of developing initiatives whereby the systems will be implemented. Policies have to include incentives so the resulting impact of such policies benefits producers and consumers of agricultural products alike. These initiatives must be taken before other interest groups use the opportunity to dictate agricultural production methods. As Batie (2) stated, agricultural issues are continually being placed on the agenda of nonagricultural interests, and nonagricultural interests are gaining prominence in agricultural issues. Financial incentives provide a means to supplement the regulatory power of government and to create an environment in which farmers' and society's interests converge and the social trap is broken.

REFERENCES CITED

1. Abdalla, Charles, and Lawrence Libby. 1987. *Agriculture and ground water quality: A public policy perspective.* Am. J. Alternative Agr. 2: 37-41.
2. Batie, Sandra S. 1988. *Agriculture as the problem: New agendas and new opportunities.* S. J. Agr. Econ. 20: 1-11.
3. Daberkow, Stan G., and Katherine H. Reichelderfer. 1988. *Low-input agriculture: Trends, goals and prospects for input use.* Am. J. Agr. Econ. 70: 1,159-1,166.
4. Davis, Otto A., and Morton I. Kamien. 1972. *Externalities, information, and alternative collective action.* In R. Dorfman and N. Dorfman [eds.] *Economics of the Environment.* W. W. Norton, New York, N.Y. pp. 69-87.
5. Griffin, Ronald, and Daniel Bromley. 1982. *Agricultural runoff as a nonpoint externality.* Am. J. Agr. Econ. 64: 547-552.
6. Harrington, Winston, Alan J. Krupnick, and Henry M. Peskin. 1985. *Policies for nonpoint-source water pollution control.* J. Soil and Water Cons. 40: 27-32.
7. Johnston, George H., David Freshwater, and Philip Favero. 1988. *Natural resource and environmental policy analysis: Cases in applied economics.* Westview Press, Boulder, Colo.
8. Madden, Patrick. 1989. *Policy options for a more sustainable agriculture.* In Proc., Conf. on Increasing Understanding of Public Problems and Policies. Farm Found., Oak Brook, Ill. pp. 134-142.
9. Olson, Mancur. 1965. *The logic of collective action.* Harvard Univ. Press, Cambridge, Mass.
10. Platt, John. 1973. *Social traps.* Am. Psychologist 28: 641-651.
11. Schmid, A. Allan. 1987. *Property, power and public choice: An inquiry into law and economics.* Praeger Publ., New York, N.Y. pp. 172-179.
12. Shortle, James S., and James W. Dunn. 1986. *The relative efficiency of agricultural source water pollution control policies.* Am. J. Agr. Econ. 68: 668-677.
13. Young, Douglas L. 1989. *Policy barriers to sustainable agriculture.* Dept. Agr. Econ. Wash. State Univ., Pullman. □

ATTRA: ANSWERS TO QUESTIONS ON SUSTAINABLE AGRICULTURE

"What can you tell me about ginseng?" Not an unreasonable question from someone interested in botany, but how about from someone looking for advice about a new agricultural enterprise? At the offices of Appropriate Technology Transfer for Rural Areas (ATTRA) in Fayetteville, Arkansas, a question about ginseng would not be unusual. It would receive the professional treatment afforded any other question related to a potentially profitable sustainable enterprise.

ATTRA is a relatively new program, started by the National Center for Appropriate Technology, headquarters in Butte, Montana, in 1987, in response to important issues, including groundwater contamination, food safety, and the desire of farmers to reduce chemical inputs and increase profitability. ATTRA has been funded annually through a federal appropriation.

ATTRA is a service that collects and analyzes information on low-input, sustainable agriculture and makes it available to extension agents, farmers, and rural communities. It is the only program in the United States dedicated exclusively to providing information about sustainable agriculture technology to the public.

ATTRA can help farmers directly on important profitability questions by providing information and technical assistance that will generate cost savings while using soil and water resources in an environmentally sound manner. ATTRA also can help farmers by putting them in contact with experts that can offer assistance with marketing and diversification options.

ATTRA is not a referral service, nor does it necessarily provide exhaustive data on a particular topic. The service is designed to give the questioner enough information to decide whether to pursue the matter further and a list of resource people and sources needed to turn the answer into a workable solution.

Sustainable agricultural technologies are attracting attention from a broad audience. Evidence for this can be seen in the number and type of requests ATTRA has received. The program has fielded more than 6,000 phone calls to date and receives more than 100 calls weekly. Farmers account for almost one-half of the total technical cases the ATTRA staff handled in fiscal year 1988. Extension agents constitute 10 percent of the users, while private organizations, rural nonfarm residents, and the general public combined for about 40 percent of the remaining cases.

By far, the largest group of questions (more than 40 percent) center on reducing use of agricultural chemicals in field, fruit, and vegetable crops. ATTRA has received specific questions on crop management practices, such as crop and variety selection, fertility practices, and pest management, specifically, biological controls on field or horticultural crops.

The second largest category of technical questions have to do with animal enterprises (15 percent). Producers want information on animal feeds, health and research, aquaculture, production of wool, wildlife game management, and beekeeping.

Policy, economics, and education constitute the next largest group of questions (13 percent). The issues that have been raised include options for farmers interested in marketing their products directly to consumers, export opportunities, and credit and finance strategies.

A broad class of miscellaneous questions (12 percent) include requests for information on storage facilities, food safety, health and nutrition, agribusiness, labor, and rural development.

The large number of inquiries related to chemicals indicates that more research is needed to develop less toxic alternatives for current farming technologies. Not only do new farming techniques need to be developed, but information providers should be advised of these options and encouraged to present them to the farmer.

The questions also reveal tremendous interest in diversification options. Farmers and ranchers view new product development as a means of responding to health and safety issues while simultaneously improving their economic standing.

With the growing interest in sustainable agriculture, ATTRA is seeking ways to expand its information network in three ways: working more closely with extension agents and other field personnel; developing information packets for limited resource farmers; and establishing better partnerships with large producers growing such commodities as corn, wheat, and soybeans.

Sustainable agriculture is here to stay because it makes economic, environmental, and common sense. ATTRA intends to be a leader in providing the best information possible to ranchers, farmers, and agricultural professionals interested in exploring sustainable farming options. If you have a question about sustainable agriculture, an answer may be only a toll-free telephone call away—1-800-346-9140.—***Robert J. Gray, president, and Diane J. Vosick, policy analyst, Resource Management Consultants, Inc., 1920 N Street, N.W. Suite 400A, Washington, D.C.***

SUSTAINABLE AGRICULTURE
Perspectives from industry

Five representatives of the agricultural chemical industry share their corporate philosophies on the concept of agricultural sustainability

Editor's Note: Following the SWCS-sponsored conference, "The Promise of Low-Input Agriculture, A Search for Sustainability and Profitability," and in planning this special issue of the JSWC, *the editorial staff asked representatives of several agricultural chemical firms the following question: How does your company define sustainable agriculture and what are you doing in terms of research to meet those goals? Following are the responses received from each of these industry representatives.*

Profitability under free enterprise

Sustainable agriculture is a broad term open to interpretation by anyone who addresses the subject. Let us refer to it here as that level of productivity that allows the agricultural enterprise to be economically competitive.

Advance planning is necessary. By knowing each field, we can use only those chemicals needed, resulting in the best economics and maximum safety to the environment. BASF long ago recognized the waste inherent in treating the soil (pre-emergent) versus treating the weeds (post-emergent). As a companion practice, we advocated narrow rows in soybeans for a quicker canopy and reduced weed competition.

We also found that splitting the application of herbicide and applying the first spray when weeds were smaller was effective; sometimes, the second application was unnecessary.

We additionally found that on certain soils tillage is not needed. Not only do producers save the time, fuel, and equipment needed for tillage, but weed pressure sometimes declines.

No-till also offers the dramatic saving of soil, thereby protecting long-term productive capacity, that is, sustainable agriculture.

So, we submit the hypothesis of (a) post-emergent chemistry, (b) narrow rows, (c) split applications, and (d) no-till practices. Each of these practices in their own way offers a savings consistent with profitability under the free-enterprise system. That means sustainable agriculture to BASF.—***Carl E. Richgels,*** *Sales Development Manager, BASF Corporation, 100 Cherry Hill Road, Parsippany, New Jersey 07054.*

A management system

Despite all the publicity, the term sustainable agriculture clearly means different things to different people.

Some people believe it means returning to the 1930s or 1940s with low yields and low profits for American farmers. Others believe it means organic farming, with no use of commercial fertilizers and pesticides. Still others think it will help save the family farm by increasing profits through reduced expenses while maintaining the same or slightly lower yields. Some even believe agricultural policies should be significantly changed to encourage farmers to practice sustainable agriculture.

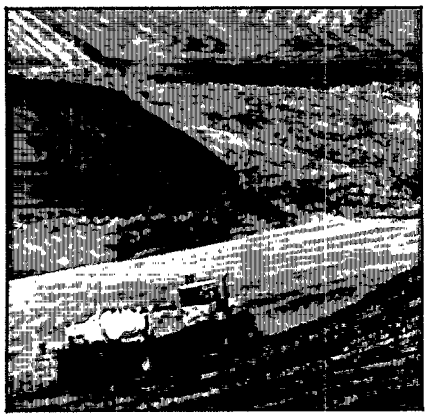
We share the same perspective on sustainable agriculture that Dr. Myron Johnsrud, administrator of the U.S. Department of Agriculture's Extension Service, recently provided:

"Sustainable agriculture in its best definition provides an opportunity for U.S. agriculture to objectively evaluate best management practices within the context of profitability, environmental soundness, and social acceptability. It is a systems approach to crop production that optimizes the effectiveness of inputs, including producer management. It is characterized by high yields and low unit costs. In reality, sustainable agriculture is a concept without a succinct definition, but can vary from region to region, even farm to farm and year to year."

We believe sustainable agriculture is a management system that maintains and enhances the ability of U.S. agriculture to meet human and environmental needs now and in the future.

It is also a farming system that uses inputs—both those available as natural resources on the farm and those purchased—in the most efficient manner possible to obtain productivity and profitability from farming while minimizing adverse effects to the environment.

Dow will continue to support sound research programs to provide the technology to enable U.S. agriculture to become the most productive and efficient of any in the world.—***Samuel J. Barrick,*** *Public Affairs Specialist, North American Agricultural Products, Dow Chemical U.S.A., P.O. Box 1706, Midland, Michigan 48641-1706.*



Profitability and practicality

The $64,000 question. Sustainable agriculture will mean a "profitable" American agriculture by optimizing the efficient use of inputs, conserving our natural resources, ensuring food safety, and preserving our environment.

In my opinion, if a method of farming is not profitable, then it cannot be sustainable. Low-chemical production alternatives that rely on crop rotations, natural fertilizers, and biological pest control are not necessarily sustainable. In reality, they may be more sustainable in certain cases and not in others. To date, there is not sufficient test data to support the premise that "low" is "sustainable." We are not confident that the sacrifice of yield offset by more intensive management is sustainable for American agriculture. In the end, profit, practicality, and what's right for our country's well-being will sustain American agriculture.

ICI's research is dedicated to sustaining American agriculture. Our basic research efforts are devoted to registering; reregistering; improving; testing; formulating; and comparing performance to rates, including major efforts in biotechnology and seeds. We are testing and introducing a portable filtration system for removing resinates from agricultural application equipment and the environment. In concert with the National Agricultural Aviation Association, we are testing new ICI-developed, low-drift aerial application nozzles to improve deposition and reduce drift. In partnership with *Custom Application* magazine and custom applicators, we have founded a Custom Application Institute dedicated to improving application technology and methods for proper and accurate deposition. We have and are adding to an ICI video library on product and proper use "how to's". We have developed computer models to help growers optimize inputs in the production decision-making process—"Expert," "Economics of No-Tillage," and "The Total Competitive Load."

Most importantly, our people are truly dedicated to sustaining American agriculture and the environment.

In addition, ICI is introducing a major LISA (Leadership in Sensible Agriculture) project in concert with five commodity organizations. This project will test, compare, and share several sustainable farming practices with the commodity groups. It also will be a clearinghouse for current information on sustainable agriculture to the commodity and environmental groups. Eventually this project will be shared with our global partners in other countries.

Finally, ICI will continue its support of soil and water conservation through its active promotion of conservation/no-tillage, via ads, videos, field specialists, cover crop programs, and our "Farm Ugly" promotional campaign in support of compliance. In sponsorship with *Farm Chemicals* magazine and the Conservation Technology Information Center (CTIC), we are sponsoring the "No-Till Tiger" contest to recognize outstanding no-till researchers, distributors, and dealer/applicators.—***R. H. Foell, Manager, Agribusiness Affairs, ICI Agricultural Products, Wilmington, Delaware 19897.***

Grabbing the reins of change in a sound system

Such terms as LISA, sustainable agriculture, conservation compliance, alternative agriculture, and similar ones have captured many headlines in the past year. At du Pont, we participate in the agricultural business in a way that supports the same general philosophy. First, let's define the words, then the concept, followed by a few comments on directions of research at du Pont.

"Sustainable": the ability to "keep up, to prolong" (Webster). "Agriculture": the science or art of cultivating the soil, producing crops, and raising livestock, and in varying degrees the preparation of these products for man's use and disposal (as by marketing).

Environment is not part of the definition, but it is generally discussed, so let's include it. "Environment": the complex of climatic, edaphic, and biotic factors that act upon an organism or an ecological community and ultimately define its form and survival.

"Sustainable Agricultural Environment": Within this phrase we include all agricultural production and environmental systems—from natural resources (soil, plant life, microbiology, air, water, etc.) to science, production, marketing, profits, and even politics.

Many highly efficient, successful American farmers exemplify the concept. They have an accumulation of more than 90 years of agricultural research, education, conservation, technology, and personal experiences upon which to build. They have developed enviable, highly efficient production and marketing systems that continue to be profitable and sustainable, meaning a production unit (family farms included) that produces enough to feed the family plus 90 others. And productivity continues to increase! The natural resource base is being preserved through contour farming, terraces, ponds, windbreaks, reduced tillage, judicious use of fertilizers, and materials to control pests.

The challenge: There are ways to improve the system to ensure an abundant and nutritious supply of food and fiber.

Improvement requires change. Change creates opportunity. While we perceive mainstream agriculture as fundamentally sound and miraculously productive, let's get on with the task of continuously improving it!

Du Pont research: First, the following are elements of our official Agricultural Products Department vision:

"It is our will to enter into a growing partnership with nature so that we play a leading role in creating a better world.

"We have a vision for continued improvement in the quality of life. We intend to have an exciting new collaboration with nature...where, combining nature's gifts and ours, we greatly exceed today's knowledge of what is possible.

"We will work everyday to point the

way...thrive on change and thus...prosper. In this way we will have the freedom to choose a destiny that benefits our customers, shareholders, our neighbors, and ourselves."

Second, please recognize that we offer to farmers crop protection products for use in production systems to supplement natural or cultural pest control practices. Pests prevent plants and animals from reaching their natural productive capacity. Specifically, we offer products that help farmers manage problems created by insects, weeds, diseases, and nematodes; problems that he or she cannot manage by cultural or crop rotational practices alone.

Third, du Pont's research direction is to discover and develop products or procedures that follow from the above vision. We focus on low use rates, products with insignificant toxicity; we deliver these products in packaging systems that minimize or eliminate environmental hazards, that minimize groundwater problems; and we develop application procedures and schedules that allow growers to deliver quality produce that is acceptable to the public.

Our biotechnology research is exploring nonchemical methods of pest control. Our analytical technology can now detect chemical residues in food, soil, water, and air at parts per billion and even parts per trillion for most of our offerings. This technology will allow us to further sharpen our ability to develop crop protectant use programs with insignificant residues.

In summary, we believe the agricultural system is fundamentally sound, highly efficient, and miraculously productive. Our food supply is the most abundant, most affordable, and safest in the world. It is the best! We all know these things.

We recognize our crop production technology is just one small part of this "systems" approach to an environmentally sound, sustainable agriculture, even though it is frequently the most criticized part of the system.

We are committed to research in chemistry, biology, biotechnology, analytical technology, improved application/delivery systems, environmentally responsible packaging and formulations. This research is supported in the field with a technical field sales and development staff that, through extensive educational efforts, work through distribution, university research and extension, conservation, farm media, and other channels to deliver these technologies to those who farm.

Again, our intentions are, like those who farm as well as those who are critical of current farming systems, to do what is good for society—to be a part of the solution, not the problem. And like those who farm, we recognize there is room for improvement. Our goal is, together with our customers, to grab the reins of change, and to do so enthusiastically.

Let's all work together to improve it. However, let's start with the current highly efficient, productive, profitable environmentally conscientious farmers as our reference point!—***Dale R. Darling,*** *Agricultural Products Department, E. I. du Pont de Nemours & Company, Walker's Mill, Barley Mill Plaza, P.O. Box 80038, Wilmington, Delaware 19880-0038.*

Efficient and responsible

Sustainable agriculture is a management system that uses inputs, both on-farm and purchased, in the most efficient and responsible manner possible to obtain productivity and profitability from a farming operation while preserving and enhancing the quality of the environment.

IMC Fertilizer has and continues to support many activities related to attaining and maintaining sustainable agriculture. Among those activities are the following:

► "Ag Issues for the 90s" Forum, attended by leaders in agricultural research and administration, agricultural lenders, media representatives, agricultural trade association, and other interested groups, such as the League of Women Voters. Topics include agronomic research and demonstration, environmental concerns, government regulation and the 1990 farm bill, food safety, risk management, and media impact on agriculture.

► Permanent endowment of a graduate fellowship at the Department of Soil and Crop Science, College of Agriculture and Life Sciences, Texas A&M University. Areas of interest could range from current economic-related areas, such as sustainability of agriculture and maximum economic or efficient yield, to those of soil chemistry and fertility.

► Financial support for the research project, "Agricultural Competitiveness, Farm Input Use, and Environmental Quality" directed by C. Ford Runge, director of the Center for International Food and Agricultural Policy at the University of Minnesota.

► Continuing support of programs of the American Society of Agronomy, including awards for significant research accomplishments via the Agronomic Science Foundation and of a "government fellow" from among the society membership who spends a year in Washington, D.C., working with legislators and administrators concerned with agricultural topics.

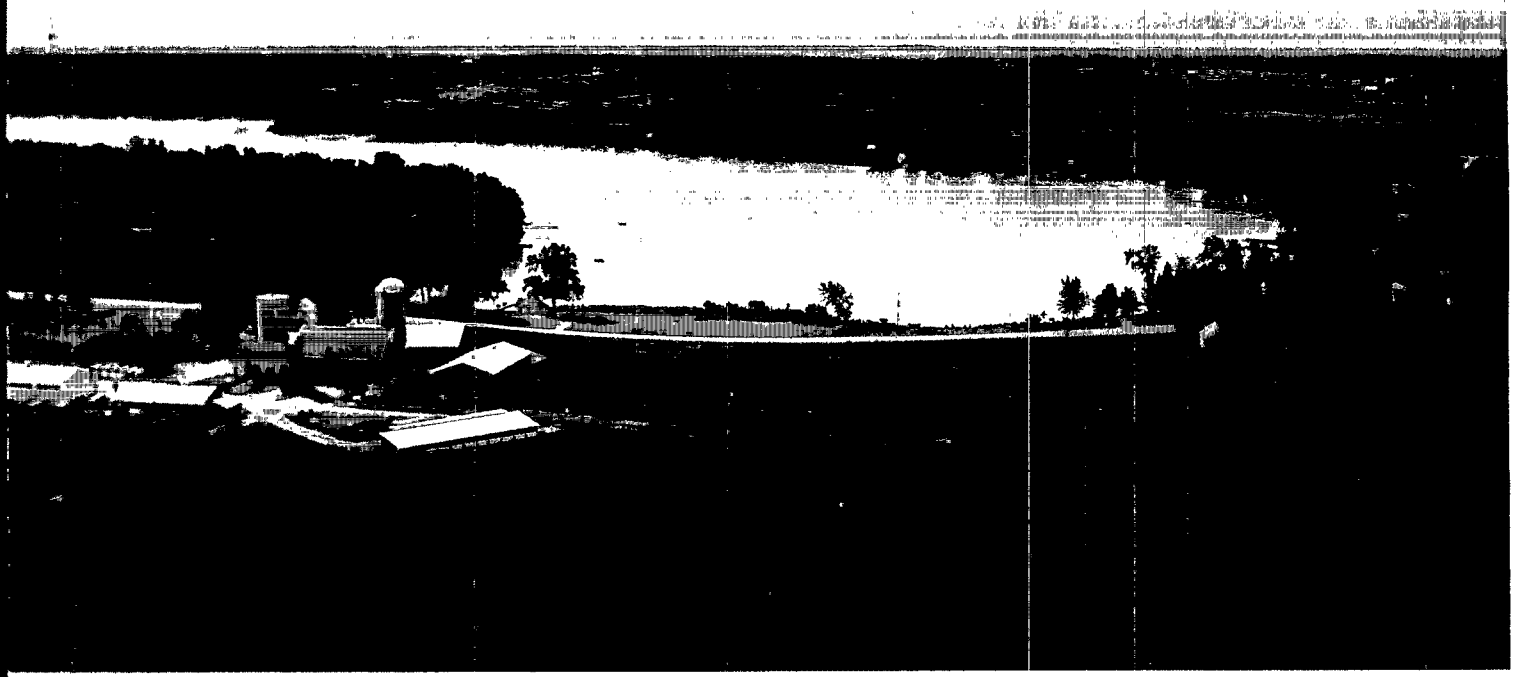
► Sponsorship of summer workshops on soil fertility and sustainable agricultural topics for teachers of vocational agriculture under the auspices of the National Vocational Agriculture Teachers Association.

► Financial support of research programs funded by the Foundation for Agronomic Research and the Fluid Fertilizer Foundation.

► Continuing support of the educational programs of the Potash & Phosphate Institute, including financial grants for graduate students in agronomy and soil science.

► Periodic support of agronomic research at state and provincial universities and experiment stations upon request from the investigators conducting the work. Support may include funding, soil and plant analysis, and fertilizer materials, depending upon the need of the researcher. In recent years, the company has contributed to 30 research and demonstration projects in the United States and Canada.

► Production and distribution of a range of print and audiovisual materials concerned with subjects of interest to farmers and the fertilizer industry, for example, soil testing, crop production, responsible fertilizer use, safety, and communications. IMC Fertilizer recently released a 10-minute videotape and a brochure entitled, "Facing Facts about the Future of Agriculture." Single copies of this brochure and tape are available without charge.—***Lindsay D. Brown,*** *Director, International Marketing Program, IMC Fertilizer, Inc., 501 East Lange Street, Mundelein, Illinois 60060.*



Soil Conservation Service

Sorting out the environmental benefits of alternative agriculture

By Pierre Crosson
and Janet Ekey Ostrov

PROPONENTS of alternative agriculture contend that it has significant environmental advantages over the conventional system now followed by most crop and animal producers in the United States. Farmers do not adequately reflect these advantages in their economic calculations because most of the advantages, such as reduced off-farm damages to soil and water quality, accrue to others. If the environmental advantages of alternative agriculture are real, the market system that fundamentally drives American agriculture will undervalue alternative agriculture relative to the conventional system. For this reason, policies designed to stimulate alternative agriculture should be considered.

We use alternative agriculture here to mean the wide range of practices indicated by terms such as "low-input," "organic," and "regenerative" agriculture. The U.S. Department of Agriculture (USDA) definition of organic farming describes the system we have in mind: "...a production system which avoids or largely excludes the use of synthetically compounded fertilizers, pesticides, growth regulators and livestock feed additives. To the maximum extent feasible organic farming systems rely upon crop rotations, crop residues, animal manures, legumes, green manures, off-farm organic wastes, mechanical cultivation, mineral bearing rocks and aspects of biological pest control to maintain soil productivity and tilth, to supply plant nutrients, and to control insects, weeds and other pests" (*32*).

Pierre Crosson is a senior fellow and Janet Ekey Ostrov was a research assistant at Resources for the Future, 1616 P Street, N.W., Washington, D.C. 20036.

Comparing system economics

Farm-level comparisons. Most of the literature on the comparative economics of alternative agriculture is cast at the farm level; typically, the short-term profitability of alternative farms is compared with that of conventional farms. With one important exception, the studies we reviewed (*1, 10, 14, 16, 17, 25, 30, 32*) showed that the alternative farming systems were less profitable than the conventional systems.

The exception was work reported by Lockeretz and associates (*18, 19, 20, 21, 22*). They found little difference in profitability between the organic and conventional Corn Belt farms they studied from 1974 through 1978. Although the organic farms had lower yields, this was offset by lower costs—reduced outlays for fertilizer and pesticides more than offsetting increased labor costs. Consequently, net income per acre averaged over the five years was about the same on the two sets of farms.

In an analysis of these results, however, Madden noted that from 1974 to 1977 severe drought affected some parts of the study area. In 1978, when rainfall approximated

the long-term average, per-acre net income on the organic farms averaged 13 percent less than the comparable county averages.[1] Madden does not give a reason for this, but one possible explanation is that organically farmed soils have greater water-holding capacity than conventionally farmed soils, giving organic farms relatively more favorable yields in dry years.

In the studies reviewed, the most obvious reason for the lower profitability of the alternative systems was the yield penalty imposed as a result of committing large amounts of land to low-value rotational uses, both to provide nutrients and to control pests. The studies are less clear about other causes of the yield penalty, but difficulties of controlling pests without pesticides, particularly weeds, is a likely factor. Weed problems were a major concern of the organic farmers surveyed by Lockeretz and associates (*22*), and the Council for Agricultural Science and Technology (*6*) cites a number of sources indicating that organic farmers name weed control as their number one problem (as it is of most conventional farmers, according to CAST).

Fawcett (*12*) notes that herbicides control fast-growing weeds that compete with emerging corn and soybean plants when soil temperatures are cool, thus permitting earlier planting in the spring than would be possible if weeds were controlled by cultivation. Fawcett also asserts that herbicides give farmers greater flexibility in the timing of cultivation, and perhaps more important, although Fawcett does not label it so, herbicides permit continuous cropping. Herbicides permit farmers to keep more of their land in relatively high-value uses more of the time than would be possible using a rotational system of weed control.

Although the literature gives less attention to the economic effects of the ban on insecticides in alternative farming systems, an adverse, indirect effect can be inferred from the fact that insect control is one of the important reasons why alternative systems rotate land among various crops, some of which are of relatively low value.

The CAST report (*6*) gives considerable weight to banning fungicides in alternative systems of producing some fruits and vegetables. According to the report, foliar fungicidal sprays are the only feasible means of disease control for such plants as apples and tomatoes. The CAST report also notes that pesticides allow control of disease and insect damage in fresh fruits and vegetables after harvest, making it more possible to store and ship them over longer distances than is feasible for the same crops grown organically. Thus, the ban on using these materials may make the market for alternatively produced fruits and vegetables smaller than that for their conventionally produced competitors.

Another question is whether substituting organic for inorganic sources of nutrients contributes significantly to the yield difference between alternative and conventional systems. Although there is agreement that manure and crop residues are the major sources of organic fertilizers used in alternative agriculture, scientists disagree whether such practices exact a yield penalty. Based on data from the Rodale farm in Kutztown, Pennsylvania, Harwood (*14*) asserts that "the potential for meeting crop nitrogen needs from legumes in rotation has been grossly underestimated by American scientists."

The findings of Papendick and associates (*28*) support those of Harwood. Olson and colleagues (*26*), however, estimated the yield effect of substituting organic for inorganic sources of nutrients on field crops and found it to be substantially negative. They assumed that yields in the 1940s reflected conditions of minimal use of inorganic fertilizers and projected the increase of these yields to the late 1970s on the assumption that the only factor in the yield increase was genetic improvement in plant cultivars. They then used these estimated yields in a comparison of the economics of conventional and alternative systems.

This seems to be a questionable procedure because it ignores all advances in knowledge of crop production since the 1940s except those embodied in improved plant cultivars. It also ignores the fact that much plant breeding after 1940 was aimed at providing fertilizer-responsive cultivars to take advantage of the declining real price of inorganic fertilizer, particularly nitrogen.

If organic sources of nitrogen had continued to be as cheap relative to inorganic nitrogen as they were in the 1940s, research on plant cultivars and farming practices probably would have given far more attention to developing techniques for using organic sources. In this case, present yields of alternative agriculture likely would compare much more favorably with yields of conventional agriculture than the study by Olson and associates estimated. Indeed, what is now called "alternative" agriculture might be conventional agriculture.

The finding of Lockeretz (*22*) that variable costs of alternative agriculture are less than those of the conventional system is supported in the other studies reviewed. The main reason is the saving in purchases of inorganic fertilizer and pesticides. The Lockeretz study found that the alternative farmers used only slightly more labor than the conventional farmers. Other studies, however, show significantly more labor with the alternative system (*25, 30*).

In some instances the economic disadvantages of alternatively grown products is offset, at least partially, by their ability to command premium prices in specialty markets. The literature gives many references to this, the most complete account being that of Oelhaf (*25*), whose study was done in the mid-1970s. Whether the price differentials he found still exist is uncertain.

Although the economic disadvantages of alternative agriculture may explain its failure to seriously challenge the conventional system, economics may not be all there is to it. Some farmers may be ignorant of the advantages of alternative agriculture, and others may have other noneconomic reasons for not adopting it. Blobaum (*2*) did a study of obstacles to adopting organic farming methods, focusing on noneconomic barriers. Based on survey responses from 214 organic farmers in the Midwest, he concluded that in their personal characteristics they were much like conventional farmers and were motivated mainly by the same practical considerations.

When asked to list obstacles to adopting alternative farming systems, the farmers surveyed most often named lack of information about practices; lack of marketing information, especially about the availability of markets offering premium prices for alternatively produced output; and the need for more research, particularly about weed control in alternative farming systems. Some also indicated that the supply of organic fertilizers and other inputs was a problem.

Blobaum did not consider the management requirements of alternative agriculture as a barrier to conversion. Management was not prominently discussed in the literature on economics we reviewed. Clearly, however, alternative agriculture requires more management time and skill than conventional agriculture. In a discussion of some of the key characteristics of successful organic farmers, Madden asserted that they are "superb managers" with complete knowledge of their farm operations.[2] Eliminating inorganic fertilizers and pesticides means that the farmer must have enough understanding of the complex relationships among crops, weeds, insects, diseases, and determinants of soil fertility to suppress those things that threaten the crop and encourage those things that make it thrive. Organic farmers also must be more careful about the timing of their operations, as Fawcett's (*12*) discussion of the advantages of herbicides indicates.

The more demanding management re-

[1]Madden, Patrick. 1987. "Economic Evaluation of Alternative Farming Practices and Systems." Unpublished paper.

[2]Ibid.

quirements of alternative agriculture may be a barrier to its more widespread adoption. Time spent in acquiring managerial skills and then applying them on the farm is time not available for other purposes. Many farmers work part-time off the farm, and for them more on-farm work has an opportunity cost measured by lost off-farm income. More on-farm work also means less time available for recreation, for family life, and for other pursuits of value to the farmer.

Conclusions on farm-level economics. The literature reviewed leaves little doubt that at the farm level alternative agriculture, as it is now practiced, is less profitable than conventional agriculture. This is not a surprising finding. If it were not so, alternative agriculture would have already replaced conventional agriculture or would be well on its way toward doing so—which it is not.

Alternative agriculture is less profitable because what it saves in fertilizer and pesticide costs is not enough to compensate for the additional labor required and for the yield penalty it suffers relative to conventional farming. The main reasons for the yield penalty appear to be the necessary rotation of main crops with low-value legumes and the difficulty of controlling weeds without herbicides.

Large-scale comparisons. What would the economics of alternative agriculture look like if the system were to wholly displace the existing system? The question has been inadequately studied. Madden says that at present the economic consequences of a large-scale shift to alternative agriculture have no credible evidence. Nevertheless, some tentative inferences can be drawn.

Oelhaf (*25*), Olson and associates (*26*), and CAST (*6*) agreed that a large-scale shift to alternative agriculture would increase production costs and set off a variety of other economic consequences that would be favorable for farmers but unfavorable for the rest of society. Farmers would benefit because prices would rise more than production would fall. Thus, gross farm income would increase more than costs.

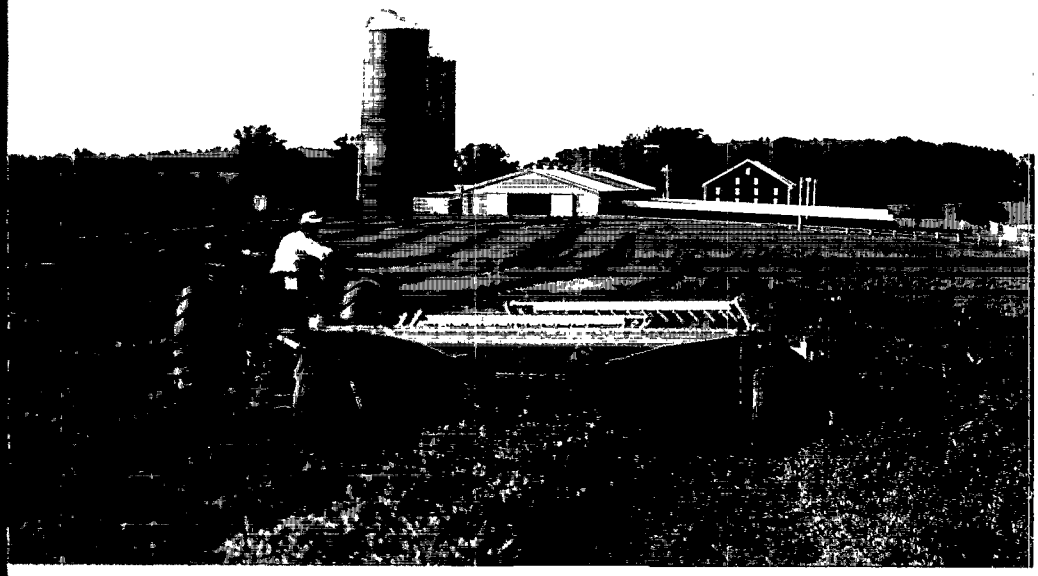
But the studies disagreed about the severity of the cost increase and the related consequences, Oelhaf (*25*) estimating a smaller cost increase than Olson and associates (*26*) and CAST (*6*). An important reason for Oelhaf's lower estimate is that he expects alternative agriculture to impose a lower yield penalty. In our judgment, Oelhaf's estimate of the penalty probably is closer to the mark than the estimates of CAST and, especially, of Olson and his associates.

The Olson and associates study (*26*) used a model of the U.S. agricultural economy to estimate the economic consequences of using alternative agricultural systems to meet a late 1970s level of demand for farm output. No inorganic fertilizers or pesticides were permitted in the alternative system. Their results are determined largely by their assumption that the wholesale shift to alternative farming would exact a large yield penalty. For reasons given earlier, however, their procedure for estimating the yield effect of substituting organic for inorganic sources of nutrients is questionable.

Their procedure gives a much larger yield penalty—50 percent for corn, wheat, and soybeans, 70 percent for other feed grains—than that found in the studies by Lockeretz and associates (*22*), Helmers and associates (*16*), and others in the literature we have reviewed. If the penalty were less than Olson and associates assumed, the cost, price, and production consequences would not be as unfavorable for alternative agriculture as those results indicated.

Yield penalties from rotational uses of land in alternative systems can make such systems less profitable than conventional ones.

Sperry-New Holland



CAST (*6*) estimated that a complete shift to alternative agriculture would reduce yields of most crops 15 to 25 percent, partly because organic sources of nitrogen would be inadequate to support current yields and partly because of losses from weeds, resulting from the ban on herbicides. CAST argues that to maintain production with a 15 to 25 percent yield reduction would require an increase in cropland of 18 to 33 percent if the land were of the same quality as land currently in production.

Like Olson and associates, CAST concluded that a wholesale shift to alternative agriculture would increase production costs, drive up supply prices, reduce amounts demanded (and hence production), and make farmers as a group economically better off at the expense of the rest of society. CAST also considered distributional effects among regions and farmers and concluded that the corn, soybean, and cotton-growing areas of the South and Southeast would be relatively disadvantaged because organic systems for combating the severe weed and insect problems in those regions would be less effective than in the Midwest and other areas growing those crops. Regions having inadequate supplies of manure or where growing legumes is uneconomical, as in dryland wheat-growing areas, also would be negatively affected.

CAST also concluded that because the switch to alternative agriculture would require more cropland, erosion would increase. Finally, land prices would rise, reflecting the increase in net farm income, and farm employment and wages would rise because of the relatively labor-intensive nature of alternative agriculture.

Oelhaf (*25*) estimated the macroeconomic consequences of producing 1974 output with alternative agricultural systems. Like the Olson and associates and CAST studies, he found that production costs would be higher and that more land and labor would be required. Although Oelhaf's conclusions are directionally the same as those of Olson and associates and of CAST, quantitatively they show a smaller cost increase and, therefore, less severe direct impacts as a result of a shift to alternative agriculture.

The results of each of these studies are critically affected by the estimated yield penalty of alternative agriculture relative to conventional agriculture. All three studies agree that a penalty would be exacted, but they disagree considerably about the amount. Although the literature reviewed

supports an estimate closer to that of Oelhaf than to those of CAST and the Olson researchers, the issue is still open.

A closely related issue concerns the relationship between the conditions of supply of organic matter and wholesale adoption of alternative agriculture. As noted earlier, crop residues and animal wastes are the principal sources of organic wastes potentially available to agriculture. Power and Doran (*31*) present data showing that the nitrogen content of all organic wastes produced in the United States (apparently in the late 1970s) was 8.1 million tons, 62 percent of it in animal wastes and virtually all the rest in crop residues.

The nitrogen content of fertilizers used by farmers at that time was 9.1 million tons, most of which was applied to cropland. These numbers indicate that even if 100 percent of the nitrogen in crop residues and animal wastes could be made available to farmers on economical terms it would not be enough to replace nitrogen fertilizers, unless the losses of nitrogen in waste material were substantially less than the losses of fertilizer nitrogen.

This raises two important questions. First, could all of the nitrogen content of crop and animal wastes be made economically available to farmers? Second, are the losses of nitrogen from wastes less than from fertilizer?

Because an estimated 70 percent of crop residues already is returned directly to the soil (*30*), the nitrogen in this source is already available to farmers. The issue, therefore, is the economics of using the nitrogen in animal wastes, 61 percent of which is excreted in unconfined habitats (*30*), most of it on rangeland and pastureland rather than on cropland. Because of the high (75-90 percent) water content of animal waste (*6*), the cost of collecting and transporting it is high relative to the price of an equivalent amount of nitrogen in fertilizer at current prices.

With respect to the second question, estimates of nitrogen loss from fertilizer typically range from 30 to 50 percent or more. The nitrogen, as nitrate, is leached to groundwater, carried away in runoff, and volatilized by denitrification. Losses of nitrogen from animal wastes, however, appear to be high as well. CAST (*6*) cites the 1978 USDA study on use of organic wastes as indicating that 63 percent of the nitrogen in manure now returned to the land is lost to volatilization and leaching, and that at best this could be reduced to 45 percent. According to CAST, this would increase the available amount of nitrogen from collectible manure from about 9 percent to 12 percent of the amount now supplied in fertilizer.

The only source of organic material that has much promise for replacing nitrogen fertilizer on a significant scale over the next decade or so is leguminous crops. This, of course, is what alternative agriculture proposes to do. Apart from whether these crops can produce enough nitrogen to replace that now available in fertilizer—an unsettled question—the necessity of including these crops in rotation with main crops is the primary reason for the lower yields of the latter per acre of land in the rotation. And this yield penalty is a principal reason for the conclusion of all the studies consulted that wholesale conversion to alternative agriculture would drive up the costs of agricultural production, increase the amount of land in crops, and have unfavorable (except for farmers) macroeconomic consequences.

Conclusions on large-scale comparisons. On balance, we conclude that a wholesale shift to alternative agriculture under current conditions would have unfavorable macroeconomic consequences, but that these probably would be closer to those estimated by Oelhaf (*25*) than to those by Olson and associates (*26*) and CAST (*6*). An important reason for Oelhaf's lower estimate of the severity of the cost increase and related consequences is that he expects alternative agriculture to impose a lower yield penalty. Our reading of the literature suggests that Oelhaf's estimate of the penalty is closer to the mark than are the estimates of CAST and, especially, of Olson and his associates.

Sustainability comparisons. We define a sustainable agricultural system as one that will indefinitely meet rising domestic and foreign demand for food and fiber at constant or declining real economic and environmental costs of production. A principal tenet of the alternative agriculture movement is that the current U.S. agricultural system is not sustainable in this sense. The reasons are that the existing system (a) generates enough erosion to seriously threaten the long-term productivity of the soil; (b) destroys useful biota in the soil through its heavy use of inorganic fertilizer and pesticides, again posing a threat to the soil's long-term productivity; and (c) relies heavily on fossil fuel sources of energy, which in time will be exhausted.

Erosion and soil productivity. Studies of the long-term effects of erosion on soil productivity done with the Productivity Index (PI) model, with the Erosion Productivity Impact Calculator (EPIC) model, and with regression analysis at Resources for the Future (RFF) agree that continuation of present rates of U.S. cropland erosion for 100 years would reduce crop yields at the end of that period by, at most, 5 to 10 percent from what they otherwise would be (*8*). If technological advances increase yields over that period at only half the annual rate experienced over the last 40 years, the negative yield effect of erosion would be offset several times over.

If USDA (*33*) is right in expecting the amount of land in crops to decline over the next 50 years, erosion will decline also, probably proportionately more than the decline in cropland because production will tend to concentrate on less erodible land. In this case, the long-term threat of erosion to soil productivity would be even less than presently estimated by PI, EPIC, and RFF.

Conventional systems and soil biota. The evidence is insufficient to conclude that the effects of conventional agricultural practices on soil biota are destructive enough to threaten the sustainability of U.S. agriculture. Poincelot (*30*) asserts that there is a "direct relationship" between organic matter in the soil and the population and distribution of beneficial soil biota. This relationship is generally accepted in the literature. Oelhof (*25*) says it is also generally accepted that with soil, climate, and other relevant conditions the same organic farmers typically achieve higher organic content in their soils than conventional farmers do.

It follows that the soils of organic farmers are usually richer in soil biota than are the soils of conventional farmers. It is not clear, however, that the difference raises an issue of long-term sustainability. It is extensively documented (*9*) that badly eroded, biota-impoverished soils can be restored to rich fertility over a period of some years by adopting management techniques—such as those of alternative agriculture—that build soil organic matter. The process takes time and involves some expense, but it is not rare. Consequently, even though conventional agriculture severely reduces soil organic matter and related biota—which it may but does not necessarily do—the losses need not be permanent. If economic conditions favor it, the soils can be restored. Restoration, of course, costs something, but that is an issue of the comparative economics of alternative and conventional systems. It is not an issue of long-run sustainability.

Reliance on fossil fuels. The nitrogen fertilizer used in the United States is produced from natural gas, and most pesticides are petroleum-based. Because petroleum and natural gas are exhaustible resources, they will someday become more expensive than they are now, and eventually their price will become so high as to exclude them from any except the most high-value uses. Therefore, their continued use by the existing agricultural system would be inconsistent with the earlier definition of long-term sustainability.

The issue, however, is one of timing. As

long as the cost of fossil fuels, taking account of the future opportunity cost of the resource, is less than the cost of the alternatives, it is in the social interest to use fossil fuels. As supplies are used up and their cost rises, it will be in the social interest at some point to switch to cheaper energy sources and to invest in research to develop those sources so that they are available when costs of fossil fuels begin a long-term rise.

At that point, renewable sources of energy, such as those used in alternative agriculture, almost surely will become economically more important. One can argue, therefore, that to maintain the sustainability of American agriculture into the indefinite future a shift from the present system to something like alternative agriculture eventually will be necessary. But "eventually" is not now.

Conclusions on sustainability. The argument that American agriculture should shift to the alternative system over the near term because the existing system is not sustainable is not well-supported. Soil erosion under the existing system is not a serious threat to long-term productivity. The existing system may reduce soil biota, in some cases severely, relative to alternative agriculture, but there is no evidence that the damage is permanent. Finally, the dependence of the existing system on exhaustible energy sources implies that the system eventually must be abandoned for one, such as alternative agriculture, that relies mainly on renewable energy sources. But the relative prices of exhaustible and renewable energy sources clearly indicate that "eventually" is not now.

Environmental characteristics

Pesticides and water quality. Hallberg (*13*) reported that studies of the presence of pesticides in groundwater from routine use are few compared to those of nitrates, but that this is beginning to change. He cited a study by Cohen and associates (*5*) in which at least 17 pesticides were found in groundwater in 23 states as a result of routine agricultural use. The largest number of pesticides was found in California, New York, and Iowa, but this is probably because these states engage in closer monitoring than others (*13*). As monitoring increases in other states, the number of pesticides found is expected to increase (*13*). The concentrations of pesticides in groundwater resulting from routine agricultural use are low, ranging in most cases from 0.1 to 1.0 parts per million (*13*). Hallberg cited evidence suggesting that the concentrations may be increasing, but this evidently is quite uncertain. Some increase seems likely, however, because of the increasing use of herbicides.

Most pesticides found in groundwater get there by leaching through the soil. In areas with karst-carbonate aquifer terrains, however, these contaminants can enter groundwater directly through sinkholes and related features, producing much higher concentrations than those resulting from leaching (*13*). Hallberg reported that these karst-carbonate aquifers underlie extensive areas of agricultural land throughout the United States.

Nielsen and Lee (*24*) analyzed the potential for pollution of groundwater by 38 pesticides recommended for inclusion in an EPA survey (underway as of this writing) of pesticides in groundwater. Combining information about county-level rates of use of these pesticides with other information about their tendency to leach to groundwater and the "leachability" of soils in areas where they are used, Nielsen and Lee ranked counties by their potential for groundwater contamination by these pesticides. They found 361 counties with high contamination potential and another 757 with medium potential.

Information about pesticide concentrations in surface water is even more scarce than that about groundwater. Where they occur, however, the surface water concentrations tend to be higher than in groundwater. The reason is that only highly soluble pesticides leach to groundwater, whereas less soluble compounds can be carried to surface water by runoff and, in some cases, sediment (*13*). Subsurface flow also can carry pesticides in groundwater to surface water.

For some people the presence of any amount of pesticides in groundwater or surface water is sufficient evidence of a serious problem justifying public action to remove the offending material and to prevent its further use. But as the title of a recent book, *The Dose Makes the Poison* (*27*), suggests, not all concentrations of pesticides are equally threatening and some may not be threatening at all. Clark and associates (*4*) report that mutagenic, carcinogenic, and teratogenic effects of pesticides have been documented only in cases of relatively high exposure.

Occurrences of high pesticide concentrations in water supplies appear to be fairly infrequent and localized, and by the time water reaches a customer tap, pesticide concentrations are seldom, if ever, at levels thought to produce health effects. But much remains unknown about long-term health effects of even small concentrations of pesticides (*4*), and little is known about synergistic effects among various pesticides and between pesticides and other substances.

This discussion suggests that if one word can be used to describe the current situation about pesticides and water quality, it is uncertainty—uncertainty about the concentrations of these materials in groundwater and surface water and uncertainty about the significance of the concentrations for human, animal, and plant health. Thus, it is impossible to judge to what extent alternative agriculture's rejection of pesticides would generate water quality benefits to offset the higher economic costs of these systems relative to conventional agriculture. Some offset seems likely, however.

Pesticide residues on food. The literature presents little documented evidence that pesticide residues on food are in fact a serious threat to human health. A 1987 report by the National Research Council (NRC) estimated that pesticide residues in food consumed by Americans would increase the probability of contracting cancer over a 70-year lifetime from 25 to 25.1 percent, an increase of 0.4 percent. The estimate is low by comparison with other health risks in American society. It should be noted, however, that the NRC's estimate refers only to cancer risks from pesticide residues in food. Other risks, such as birth defects, were outside the purview of the study.

The CAST report (*6*) cited an earlier NRC study of the acute toxicity of pesticide residues in food. This study found that U.S. per-capita consumption of these residues was about 40 milligrams, more than half being pesticides no longer in use at that time. The aggregate acute toxicity of these residues was roughly equivalent to the acute toxicity of one aspirin or one cup of coffee. But the CAST report noted that longer term effects of chronic exposure to such small amounts of pesticides had not been resolved satisfactorily by the available scientific evidence. This uncertainty is still unresolved.

Handling pesticides. Pimentel and associates (*29*) estimated deaths from pesticides by accident, homicide, and suicide to have been several hundred per year in the 1970s. They estimated illnesses from pesticide poisoning to be in the tens of thousands. These numbers are subject to considerable error, as the researchers recognized, because state reporting of the necessary data is sometimes spotty, and the data about accidents are inherently difficult to collect. Nonetheless, the human and economic cost of pesticide poisoning of farmers, their families, and their hired workers appears to be significant. The fact that alternative agriculture would drastically reduce, if not eliminate, this cost would seem to be its most important environmental advantage related to conventional agriculture.

Nutrients. Nitrogen and phosphorus in runoff and carried by sediment contribute

to eutrophication of surface water bodies, and nitrogen in the form of nitrate is leached to groundwater, where it may pose a threat to human and animal health. Oelhaf (*25*) stated that "heavy manuring causes the same nitrate problems as heavy chemical applications." And CAST (*6*) asserted that the nitrate in fertilizer is more readily available to the crop than that in manure or leguminous crops. Consequently, the amount of the nutrient remaining in the soil after harvest is greater with these sources, suggesting that they may contribute more to nitrate pollution than does inorganic nitrogen fertilizer.

Thus, the potential for nitrate damage to water quality appears to be about the same for alternative and conventional agricultural systems. Whether the two systems differ in fact in the amount of damage is unknown. The Papendick and associates' report (*28*) asserted that "organic farmers are apparently able to control availability and release of nitrogen through various techniques of soil management," but went on to state that "there are little or no hard data available on leaching loss of nitrates on organic farms." It appears that any environmental benefits of alternative agriculture with respect to reduced nitrate pollution of groundwater and surface water are not substantial enough to offset the economic disadvantages of the system.

On sloping, erodible soils, alternative agriculture generally will produce much less erosion than conventional agriculture. Because much of the phosphorus delivered to surface water is carried by sediment, the erosion-reducing characteristics of alternative agriculture ought to give the system a potential advantage relative to conventional agriculture in reducing eutrophication of lakes and reservoirs where phosphorus is the limiting nutrient. The importance of this as an offset to the economic disadvantages of the alternative system, however, is difficult to judge given the lack of information about the amount of eutrophication damage, the contribution of agricultural sources of phosphorus to it, and the effect of alternative agriculture in reducing the damage.

Sediment. The Clark and associates' estimates (*4*), expressed in 1985 prices (*8*), indicated that sediment damage to surface water quality costs the nation $4 billion to $16 billion annually. Clark and associates estimated that cropland erosion is responsible for about a third of this damage. The erosion-reducing characteristics of alternative agriculture on sloping, erodible land ought to give it a clear advantage over conventional agriculture in reducing these damages. This is subject to the caveat that the relationship between reduction of erosion on the land and reduction in sediment damage downstream often is unclear (*8*).

Adrian Achterman

Wildlife benefits derived from alternative practices are a strong argument for the social value of such practices.

Moreover, alternative agriculture is not the only system with this advantage. On sloping, erodible land, conservation tillage—defined as any tillage system that leaves at least 30 percent of the previous crop's residue on the soil surface after spring planting—reduces erosion 50 to 90 percent relative to conventional tillage (*7*). But conservation tillage as typically practiced relies on herbicides at least as much as, and often more than, conventional tillage. Conservation tillage is used on roughly a third of the nation's cropland—far more land than is devoted to alternative agriculture, primarily because it is more economically competitive than alternative agriculture. Thus, conservation tillage appears to offer a more economical alternative for reducing sediment damage than does alternative agriculture. The benefits of conservation tillage in reduced sediment damage, however, could be bought at the price of increased herbicide damage—a price alternative agriculture does not have to pay.

Animal habitat. The literature reviewed gives contradictory evidence on the effects of conventional agriculture and alternative agriculture on animal habitat. Writing about the South, Healy (*15*) asserted that "on balance, the land use changes that have taken place in the South since about 1935 probably have improved carrying capacity for many game species by creating a more diverse local habitat." Healy was talking about more than crop production; however, the period of which he writes encompasses that in which crop production in the South shifted to the high-energy and chemical-based system we now call conventional agriculture.

Cacek (*3*) considered the effects of conventional agriculture on wildlife habitat in 12 midwestern states and came to a much less favorable conclusion than Healy did with respect to the South. Cacek cited a study indicating that from the mid-1950s to the mid-1970s wildlife populations in these states declined 40 to 80 percent. Cacek attributed these declines to transformation of crop production in this period, particularly the dramatic increase in the use of agricultural chemicals, a decrease in crop diversity, and the elimination of fence rows as farmers expanded to take advantage of larger equipment. The reduction in acreage in set-aside programs also was a factor. Cacek also recounted the advantages of alternative agriculture in improving animal habitat, particularly by providing nesting places for birds and eliminating the danger of pesticide poisoning.

USDA projects a decline of tens of millions of acres in crops over the next 50 years (*33*). Much of this land will shift to a variety of urban and other nonagricultural uses, almost surely with unfavorable habitat consequences. Habitat on the land that shifts out

of crops but remains in some low-value use in agriculture, however, should improve. What the net habitat effect of these changes in land use would be is not clear from the information provided by USDA.

For a given amount of crop and animal output, alternative agriculture uses more land than conventional agriculture does. Consequently, a large-scale shift to alternative agriculture almost certainly would hold more land in agriculture than the USDA projections indicate, which should result in more and better animal habitat than the USDA projections imply. Not only would the shift of land out of agriculture be less than in the USDA projections, but habitat on all land devoted to crop production would be improved, if Cacek (*3*) is right about the relative habitat benefits of alternative agriculture.

This is a strong argument for the social value of alternative agriculture relative to conventional agriculture. Healy's work (*15*) and that of various authors cited by Decker and Goff (*11*) indicate that many people in the United States place a high value on wildlife, both as hunters and as "nonconsumptive users," such as bird watchers. With continued growth in population and income over the next 50 years, demand for these various uses of wildlife is sure to grow, probably substantially. The benefits of alternative agriculture relative to those of conventional agriculture in providing wildlife habitat could be expected to grow correspondingly.

Conclusions on environmental comparisons. By eliminating the use of pesticides, alternative agriculture probably would provide some positive benefit in improved water quality relative to conventional agriculture. Moreover, because alternative agriculture reduces erosion on sloping and more erodible land, it probably has some advantage in reducing phosphorus deliveries to lakes and reservoirs, although information is insufficient to judge the importance of this advantage. The evidence suggests, however, that there is little difference between alternative agriculture and conventional agriculture with respect to nitrate pollution of groundwater and surface water.

The erosion reduction advantage might be significant, however, in reducing sediment damage. Evidence suggests that these dam-

LOW-INPUT AGRICULTURE: OVERCOMING THE IMPEDIMENTS

In 1987, the Freshwater Foundation sponsored a conference titled "Agricultural Chemicals and Groundwater Protection: Emerging Management and Policy." There were two outcomes from this conference. One was the results of a questionnaire sent out to conference preregistrants. The second was a series of recommendations based on the written and verbal comments of conference attendees.

Respondents to the questionnaire represented virtually every group that has an interest in agriculture and groundwater: government agency people, university and extension personnel, farmers, farmer organizations, the agrichemical industry, public health officials, nonprofit and environmental groups, business and industry, researchers, testing firms, legislators, and the media.

Respondents were asked to rank the effect of the following forces that drive agrichemical use: advertising, the economics of staying in business, government policies, market pricing, and tradition. Sixty-two percent of the respondents identified the economics of staying in business as the greatest force driving agrichemical use, 11 percent ranked advertising as the greatest force, another 11 percent ranked tradition, 8 percent ranked government policies, and nearly 3 percent ranked market pricing.

Respondents also were asked whether sufficient information was available to allow for effective management of agrichemicals and protection of groundwater. The response was overwhelming: 20 percent said "yes," and 80 percent said "no."

To assess the adequacy of the information-sharing process, respondents were asked whether the right information was getting to the right people. Again, the response was definitive: 9 percent said "yes," 91 percent said "no." In a follow-up question, respondents said that breakdowns in the information-sharing process occurred between virtually every possible set of groups: between the agrichemical industry and the user, between local entities and the farmer, between state and local entities, and between federal and state entities.

Respondents were asked to identify the greatest constraint to effective management of agrichemicals and protection of groundwater. They identified three as being almost equal: 23 percent named lack of incentives to change current practices, 23 percent named inadequate information, and 20 percent named potential loss of income. Another 11 percent indicated inadequate communication of information, nearly 9 percent indicated conflicting information, nearly 5 percent indicated inadequate information sources, 2 percent indicated peer pressure, and 0.5 percent indicated lack of time.

When asked to identify who should bear primary responsibility for protecting groundwater from agrichemical contamination, 30 percent of the respondents suggested it should be a partnership among various governmental agencies, farmers and farmer organizations, the agrichemical industry, and society as a whole. Less than 19 percent suggested that the responsibility fell to the producers or users as an individual group, 10 percent identified federal government agencies as the responsible group, another 9 percent indicated a partnership of users and producers should be responsible, and other respondents mentioned various other groups.

Finally, respondents were asked to identify the greatest immediate need regarding agrichemical management and protection of groundwater. Fifty percent of the respondents said more information and better information dissemination were needed. Specified needs included better, clearer, more precise, unbiased information; more scientific research and an increased data base; and better dissemination and communication of information.

Conference attendees were asked to respond both verbally and in writing to a variety of issues. A list of 10 recommendations was compiled from these extensive responses. Of these, eight seem particularly appropriate in talking about low-input, sustainable agriculture and its potential for protecting water quality:

- An immediate need exists on behalf of all agencies and organizations, but particularly farmers, for information on agrichemicals and their impact on groundwater quality and public health.
- Farmers need practical, demonstrable, best management practices regarding agrichemical use and groundwater protection.
- The institutional barriers built into bank loans and government programs that encourage unnecessary or excessive agrichemical use need to be eliminated.
- Farmers need economic incentives to change current practices that rely on heavy use of agrichemicals where underlying groundwater supplies are at risk.
- Food production and commodities programs should be brought into harmony with conservation and environmental programs.
- Information and policies related to the proper disposal of pesticides and pesticide containers are needed.
- Funding at all levels—federal, state, local, and private—is needed to develop effective groundwater management plans and policies.
- Cooperation and coordination are needed at all levels of government as well as between the public and private sectors to effectively manage the impact of agrichemicals on groundwater.—***Linda Schroeder,*** *formerly manager of publications and conferences, Freshwater Foundation, now a private consultant, Delano, Minnesota, speaking at the conference "The Promise of Low-Input Agriculture: A Search for Sustainability and Profitability."*

ages now amount to billions of dollars each year.

The threat to human health of pesticide residues in food evidently is small. A wholesale shift to alternative agriculture, however, likely would yield substantial benefits in reduced deaths and illnesses stemming from pesticide application.

By holding more land in agriculture than would occur with conventional agriculture and by providing a more diverse habitat on that land, alternative systems likely would yield considerably greater benefits in improved animal habitat than the conventional system.

The extent to which these environmental benefits of alternative agriculture would offset their economic disadvantages is difficult to judge. But the offset—particularly that stemming from reduced pesticide deaths and illnesses and from habitat improvement—is probably large enough to warrant serious consideration of policies to stimulate greater farmer interest in alternative systems.

Policy implications

For the last 40 years agricultural research in the United States has been aimed at developing systems of increasing economic productivity. Systems that offered gains in environmental benefits only at some sacrifice of economic productivity were relatively neglected. Consequently, our conclusion that alternative agriculture suffers a significant economic disadvantage relative to conventional agriculture is not surprising. But the conclusion that alternative agriculture conveys environmental benefits relative to conventional agriculture suggests that policymakers should begin to give more attention to the development of alternative agriculture than they have heretofore. Although a wholesale shift to alternative systems over the next decade or so could not be justified, policies to put more resources into research on the comparative economic and environmental characteristics of alternative and conventional agriculture deserves serious consideration.

The recent National Academy of Sciences report argued that federal government commodity price and income support programs are a barrier to widespread adoption of alternative agriculture (*24*). Under these programs, farmers receive payments according to how much "base acreage" they have in program crops, principally corn, wheat, and cotton. If farmers adopt a rotational system typical of alternative agriculture, they lose base acreage, hence they sacrifice income support payments. The importance of this barrier to adoption of alternative agriculture is unknown, but we believe it carries some weight. Research on this issue would contribute to the policy discussion of how to encourage wider adoption of alternative agriculture.

With respect to environmental characteristics, policymakers should support collection and analysis of data on pesticide use and its consequences for environmental quality. With respect to economics, research on the causes of the yield penalty that alternative agriculture now suffers should have high priority. Weed control with substantially reduced use of herbicides should be the primary initial target. The objective should be a system that is more competitive economically with the conventional system while significantly less dependent on herbicides. If this research succeeds, farmers will have increasing economic incentives to adopt alternative agriculture, and the system will spread. Farmers will gain economically, and society in general will reap gains in environmental improvement.

The animal habitat benefits of alternative agriculture relative to conventional agriculture also deserve additional research attention. Analytical techniques have been developed to estimate unpriced benefits of this general sort, but the techniques have not been brought systematically to bear on the study of the relative habitat benefits of the two contending agricultural systems. If, in fact, alternative agriculture is particularly favored in this respect and if the growing future demand for wildlife services will strengthen that advantage even more, the payoff to research along this line should be high in promoting the best use of the nation's resources.

REFERENCES CITED

1. Berardi, G. M. 1978. *Organic and conventional wheat production: Examination of energy and economics.* Agro-Ecosystems 4: 367-376.
2. Blobaum, Roger. 1983. *Barriers to conversion to organic farming practices in the midwestern United States.* In W. Lockeretz [ed.] *Environmentally Sound Agriculture.* Praeger, New York, N.Y.
3. Cacek, T. 1985. *Impacts of organic farming and reduced tillage on fish and wildlife.* In Thomas C. Edens, Cynthia Fridgen, and Susan L. Battenfield [eds.] *Sustainable Agriculture and Integrated Farming Systems.* Mich. State Univ. Press, East Lansing.
4. Clark, E. II., J. Haverkamp, and W. Chapman. 1985. *Eroding soils: The off-farm impacts.* The Cons. Found., Washington, D.C.
5. Cohen, S., C. Eiden, and M. Lorber. 1986. *Monitoring ground water for pesticides.* In W. Garner and associates [eds.] *Evaluation of Pesticides in Ground Water.* Symp. Series 315. Am. Chem. Soc., New York, N.Y.
6. Council for Agricultural Science and Technology. 1980. *Organic and conventional farming compared.* Rpt. no. 84. Ames, Iowa.
7. Crosson, P. 1981. *Conventional tillage and conservation tillage: A comparative assessment.* Soil Cons. Soc. of Am., Ankeny, Iowa.
8. Crosson, P. 1986. *Soil erosion and policy issues.* In T. Phipps, P. Crosson, and K. Price [eds.] *Agriculture and the Environment.* Resources for the Future, Washington, D.C.
9. Crosson, P., and A. Stout. 1983. *Productivity effects of cropland erosion in the United States.* Resources for the Future, Washington, D.C.
10. Dabbert, Stephen, and Patrick Madden. 1986. *The transition to organic agriculture: A multi-year simulation model of a Pennsylvania farm.* Am. J. Alternative Agr. 1(3).
11. Decker, D., and G. Goff. 1987. *Valuing wildlife: Economic and social perspectives.* Westview Press, Boulder, Colo.
12. Fawcett, R. S. 1983. *Control of weeds.* In R. B. Dahlgren [ed.] *Proceedings of Management Alternatives for Biological Farming Workshop.* Iowa State Univ., Ames.
13. Hallberg, George R. 1987. *Agricultural chemicals in ground water: Extent and implications.* Am. J. Alternative Agr. 2(1).
14. Harwood, Richard R. 1984. *Organic farming research at the Rodale Research Center.* In *Organic Farming: Current Technology and Its Role in a Sustainable Agriculture.* Am. Soc. Agron., Madison, Wisc.
15. Healy, R. 1985. *Competition for land in the American south.* The Cons. Found., Washington, D.C.
16. Helmers, Glenn A., Michael R. Langemeier, and Joseph Atwood. 1986. *An economic analysis of alternative cropping systems for east-central Nebraska.* Am. J. Alternative Agr. 1(4).
17. James, Sidney C. 1983. *Economic consequences of biological farming.* In R. B. Dahlgren [ed.] *Proc., Management Alternatives for Biological Farming Workshop.* Coop. Wildl. Res. Unit, Iowa State Univ., Ames.
18. Lockeretz, W. 1980. *Maize yields and soil nutrient levels with and without pesticides and standard commercial fertilizers.* Agron. J. 72: 65-72.
19. Lockeretz, W., et al. 1976. *Organic and conventional crop production in the Corn Belt: A comparison of economic performance and energy use for selected farms.* Center for Biol. of Nat. Sys., Washington Univ., St. Louis, Mo.
20. Lockeretz, William, et al. 1978. *Field crop production on organic farms in the Midwest.* J. Soil and Water Cons. 33(3): 130-134.
21. Lockeretz, William, et al. 1981. *Organic farming in the Corn Belt.* Science 211: 540-547.
22. Lockeretz, William, et al. 1984. *Comparison of organic and conventional farming in the Corn Belt.* In D. F. Bezdicek and associates [eds.] *Organic Farming: Current Technology and its Role in a Sustainable Agriculture.* Am. Soc. Agron., Madison, Wisc.
23. National Academy of Sciences. 1989. *Alternative Agriculture.* Nat. Academy Press, Washington, D.C.
24. Nielsen, E., and L. Lee. 1987. *The magnitude and costs of groundwater contamination from agricultural chemicals.* AER no. 576. U.S. Dept. Agr., Washington, D.C.
25. Oelhaf, Robert C. 1978. *Organic agriculture.* Allanheld, Osmun & Co., Montclair, N.J.
26. Olson, Kent D., James Langley, and Earl O. Heady. 1982. *Widespread adoption of organic farming practices: Estimated impacts on U.S. agriculture.* J. Soil and Water Cons. 37(1): 41-45.
27. Ottoboni, M. 1984. *The Dose Makes the Poison.* Vicente Books, Berkeley, Calif.
28. Papendick, R. Z. Elliot and J. Power. 1987. *Alternative production systems to reduce nitrates in groundwater.* Am. J. Alternative Agr. 2(1): 19-24.
29. Pimentel, D., et al. 1980. *Environmental and social costs of pesticides: A preliminary assessment.* OIKOS 34(2).
30. Poincelot, Raymond P. 1986. *Toward a more sustainable agriculture.* AVI Publ., Westport, Conn. 241 pp.
31. Power, J. F., and J. W. Doran. 1984. *Nitrogen use in organic farming.* In *Nitrogen in Crop Production.* Am. Soc. Agron., Madison, Wisc.
32. U.S. Department of Agriculture. 1980. *Report and recommendations on organic agriculture.* 620-20-3641. Study Team on Organic Farming, Washington, D.C.
33. U.S. Department of Agriculture. 1987. *The second RCA appraisal: Review draft.* Washington, D.C. □

Low-input agriculture and soil conservation

By Klaus W. Flach

Conservation tillage, which minimizes soil disturbance and maintains a cover of crop residue on the soil surface, has opened exciting opportunities for controlling soil erosion without expensive structural conservation measures. As originally conceived, conservation tillage, to a large extent, substituted chemicals for tillage practices.

Low-input farming systems, on the other hand, seek to minimize the use of "purchased inputs," mainly the use of pesticides and chemical fertilizers, and, consequently, may be thought to require more tillage and mechanical weed control than does conservation tillage. Low-input agriculture, therefore, may be considered incompatible with the most modern and, in many places, most effective soil conservation technology.

I was keenly aware of this conflict and, a few years ago, considered it inevitable. I believe now that low-input farming and soil conservation are not only compatible but actually mutually supportive. The successful marriage of the two approaches, however, will require a willingness to cooperate and, often, a willingness to change long-held beliefs for both soil conservationists and low-input farmers.

Some effective systems

Dick Thompson, the eminent practitioner of low-input farming in Boone County, Iowa, has convinced me that ways can be found to resolve the apparent contradiction between the two farming systems. Thompson uses a ridge-till system in which he keeps a cover of plants or crop residue or even weeds on the soil during most of the year and, by doing so, effectively minimizes erosion. I also suspect, although I have no proof, that he has made his soils inherently less erodible than they were before. We can use him as evidence that low-input systems can be fully compatible with soil conservation objectives.

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Another convincing argument for the basic compatibility of low-input and soil conservation practices was made by Mary Jackson, who compared a very traditional low-input system, an Amish farm in Holmes County, Ohio, with an adjacent farm that uses modern no-till technology (*3*). The Amish farm she studied has convincingly shown little soil erosion, although conventional application of the universal soil loss equation (USLE) suggests erosion rates between 7 and 15 tons per acre. She found that rotations that include legumes and liberal manure applications, combined with the use of horses rather than heavy tractors, reduced soil compaction and greatly improved soil quality on the Amish farm.

Through this management system, organic matter content and, consequently, aggregate stability are increased and bulk densities are decreased, with the result that water infiltration rates in cornfields on the Amish farm were about seven times as high as those on the same soil under conventional no-till. There is little runoff and little erosion. She also pointed out that in the rotation used on the Amish farm the soil was left bare for only three and one-half months in a four-year rotation.

I believe that Jackson has an important message for all soil conservationists and for all farmers. In fairness, it should also be said that her findings do not necessarily apply to all Amish farms.

Critical conservation factors

As shown in the previous examples, low-input farming systems can be effective conservation systems because they provide soil cover during most of the year and because they can make better soils that have less runoff and more resistance to erosion. Through their greater use of rotations and green manure crops, low-input systems are likely to provide cover during a greater part of the year than conventional farming and especially mono-cropping systems. This is rather obvious, and I will not belabor the point. It is important, of course, that we be able to identify critical periods of the year when cover on the soil is essential and to manage the land accordingly.

We have opportunities to make better soils that are more resistant to erosion than soils that have been conventionally managed. Perhaps we can make them more resistant to erosion than they ever were. Low-input systems, because of their use of legumes and other high-residue crops in their rotations and their emphasis on manure as a source of soil fertility, can do that.

Early soil conservationists had a more holistic approach to soil conservation than we have today. They not only wanted to conserve but also to repair the damages of the past through practices that increased the organic matter content in the soil. Later generations of soil conservationists concentrated more on such things as soil loss and soil erosion equations, and opportunities to improve the quality of surface soil were pretty much ignored. The soil erodibility factor, K, of the USLE became a constant for individual kinds of soil, without any consideration that we may change K through better management.

The second chief of the Soil Conservation Service (SCS), Dr. Robert S. Salter, for example, did some fine work before he came to SCS in documenting the influence of certain crops and manure on soil organic matter (*6*). He developed "productivity indices" for each crop (*7*). Some modern work in Wisconsin that shows a close relationship between organic matter content and potential productivity proves him right. Actually, as a very young scientist, I checked Salter's work and found that his indexes predicted the organic matter content of upstate New York soils almost perfectly.

As a consequence of our rather narrow outlook on soil conservation, research on controlling soil erosion though improving soil quality almost disappeared. It came back only when experiments on conservation tillage in the 1970s and 1980s showed that conservation tillage did more than just protect the soil from the impact of rain drops; it also reduced runoff. In addition, the benefits of conservation tillage increased with time. Obviously, something was happening to the soil that could not be explained through the mechanical effects of crop residues alone.

In one experiment at Coshocton, Ohio (*2*), runoff from a watershed that had been in no-till corn for 15 years was 1.6 millimeters per year, whereas an adjacent, conventionally tilled watershed had 100 times as

much runoff, 177 millimeters. We do not know to what extent the changes in infiltration and erosivity were a direct effect of the increased organic matter level and could have been achieved with practices other than no-till that would have increased organic matter similarly. Certainly, a large part of the credit must go to soil fauna, mostly earthworms, that in undisturbed soil produce large and continuous pores that are ideal conduits for water. But low-input farming systems other than no-till, like the ones used by Dick Thompson or by Amish farmers, may produce the same liberal supply of food and the cover during much of the year that encourages earthworms. Unfortunately, hard evidence for this view is lacking at this time.

In a number of experiments at Watkinsville, Georgia (*4*), all on similar soils, double-cropping of soybeans with crimson clover during the winter and no-till nearly doubled the organic matter content and restored soybean yields in a severely eroded soil to those of its slightly eroded equivalent. In related experiments, a cover crop during the winter reduced erosion to 1.3 tons per acre from 12 tons per acre without the cover crop. In these experiments, erosion on plots under conventional tillage also was greatly reduced, suggesting that a cover crop during winter and changes in soil properties were responsible for much of the apparent improvement.

The experiments at Coshocton and the ones at Watkinsville used fertilizers and pesticides. Nevertheless, we can say with some confidence that they show the potential for reducing erosion under management systems that provide cover during critical periods and for improving infiltration and, consequently, reducing erosion if liberal amounts of organic materials are returned to the soil.

New technology for new tasks

The development of conservation systems appropriate for low-input agriculture will require more flexible conservation planning than has been possible in the past. The tools for doing this are being developed. Scientists of the Agricultural Research Service (ARS), in close cooperation with specialists in SCS, the Forest Service, and the Bureau of Land Management, are developing new models that not only will predict soil erosion more accurately but also will allow greater flexibility in developing conservation systems (*1*). The models will be simulating the actual erosion processes, not gross erosion as the current models do, and will be driven by synthetic "weather generators" that simulate long-term weather patterns for individual locations on a day-by-day basis.

The water erosion model, WEPP (Water Erosion Prediction Project), for example, will model interrill or splash erosion separately from soil detachment by rill erosion. The soil conservationist then will be able to tailor conservation practices to the dominant erosion processes. The daily time step in erosion prediction will identify when during the year critical erosion events are likely to occur so that timing the soil management steps and planting the cover crops can be related to the likelihood of such events. This capability will be particularly important in conservation plans for low-input agriculture and will result in more realistic assessments of erosion for such systems.

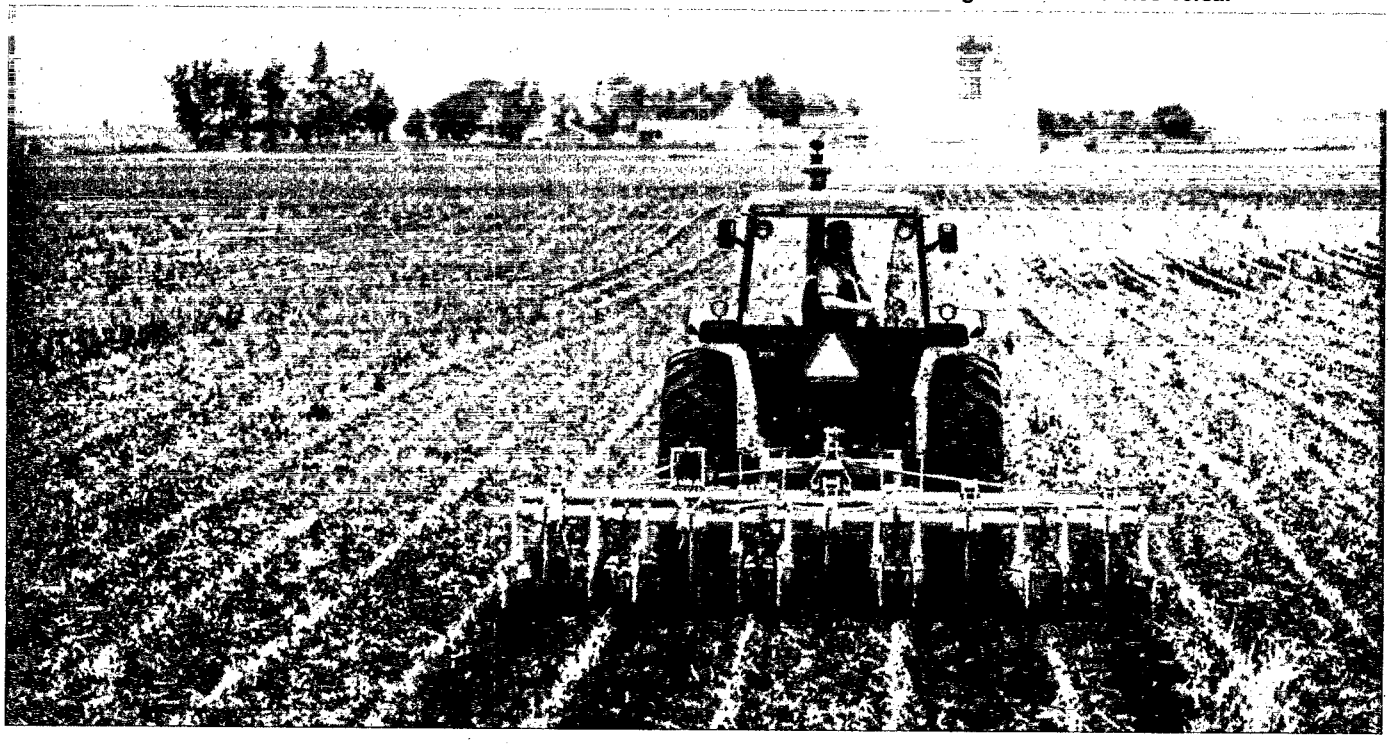
The soil erodibility factors (K) for water erosion should reflect management history much more than they do now. At this time the experimental basis for such adjustments is inadequate, but when it is developed, management history can be incorporated for an adjusted K factor.

Managing the soil-crop system

Traditional farm management has emphasized crop management for maximum return, which often has been equated with maximum yield. Soil conservation usually has been considered an add-on. The farm was planned for production, and soil conservation was planned around this production system. This, of course, has not always been so. Before the ready availability of commercial fertilizers and pesticides, rotations and mixes of livestock and crops were essential for maintaining the viability of the soil-crop system. Basically, low-input farming means going back to managing the soil-crop system as an integrated system.

We do not fully understand this system yet, but we are making progress. For example, we understand now that phosphorus is

Soil conservation practices can contribute to sustainable agricultural and vice versa.



essential for the formation of stable organic matter in the soil, and we will have to supply the soil with phosphorus if it is naturally deficient. Likewise, viable low-input conservation farming systems require an adequate supply of plant residues from the above- and below-ground parts of the plant to produce the organic materials needed to keep the soil from eroding and to improve its physical properties.

Therefore, going back to managing the integrated soil-crop system should not mean going back to farming the way it was done 100 years ago. Rather, we should take advantage of everything modern science and technology have to offer, including chemical fertilizers and pesticides, in ways that are environmentally and ecologically responsible.

Low-input and soil conservation

I postulated that the objectives of low-input agriculture and soil conservation can be compatible and supplementary. I have provided some evidence—almost none of it direct and conclusive. I have documented that the organic matter content of soils can be increased and that management practices that increase organic matter also increase infiltration; reduce runoff; and, consequently, are likely to decrease erosion. I have implied—and I am not the first to do so—that higher organic matter levels in soils are desirable, but I have no direct evidence that organic matter by itself makes soil better. Obviously, much more research on the impact of cropping systems on the quality of soil is needed. Such research must be conducted over long periods. It is, therefore, expensive and, without specific encouragement, will not be done.

Nevertheless, I believe that soil conservationists should seek to improve rather than just to conserve soil. If we stop at conserving, we will not be able to feed future generations. Bob Rodale has been calling for regeneration. I agree with him, but in many places we can do better than merely regenerate. The surface of the soil is its most critical part for plant growth and for soil protection. We obviously can damage it more than any other part, but I believe we also can improve it more. Hence, efforts to improve its quality should be given equal or more than equal weight in controlling soil erosion. If that is done, there will be no difficulties in acknowledging the contribution that low-input farming can make to soil conservation.

Surface soils can be improved only if we use all that modern science and technology have to offer. Our soils are too important to be sacrificed to dogmatic beliefs.

REFERENCES CITED

1. Anonymous. 1987. *Compilation of water erosion prediction project (WEPP) papers.* Am. Soc. Agr. Eng., St. Joseph, Mich.
2. Edwards, W. M., M. J.. Shipitalo, and L. D. Norton. 1988. *Contribution of macroporosity to infiltration into a continuous corn no-till watershed: Implications for contaminant movement.* J. Contam. Hydrol. 3: 193-205.
3. Jackson, Mary. 1988. *Amish agriculture and no-till: The hazards of applying the USLE to unusual farms.* J. Soil and Water Cons. 43: 483-486.
4. Langdale, G. W., W. L. Hargrove, and J. Giddens. 1984. *Residue management in double-crop conservation tillage systems.* Agron. J. 76: 689-694.
5. Mills, W. C., A. W. Thomas, and G. W. Langdale. 1986. *Estimating soil loss probabilities for Southern Piedmont cropping-tillage systems.* Trans., ASAE 29: 948-955.
6. Salter, R. M., and T. C. Green. 1933. *Factors affecting the accumulation and loss of nitrogen and organic matter in cropped soils.* J. Am. Soc. Agron. 25: 622-630.
7. Salter, R. M., R. D. Lewis, and J. A. Slipher. 1936. *Our heritage the soil.* Bull. 175. Agr. Ext. Serv., Ohio State Univ., Columbus. □

RECREATION AND LISA: PARTNERS IN CREATIVE STEWARDSHIP

The very nature of low-input, sustainable agriculture has led to unanimous disagreement on what the term means. There are probably no two people in any group that can agree on a definition. In my opinion, sustainable agriculture is an agricultural activity that uses the best products and procedures to increase cash returns to the producer while maintaining or improving the natural resources. The ways of achieving sustainable agriculture are not new. Most practices have been around for decades. The challenge is to be creative. Soil Conservation Service (SCS) employees working with producers need to identify farming and ranching systems that meet landowner's objectives while providing quality stewardship of the environment.

One program activity that received substantial support from SCS during the 1960s and 1970s was recreation. SCS concern for recreation was de-emphasized beginning in the 1980s, when emphasis shifted to such agency missions as the 1985 Food Security Act (FSA) and water quality. Today, some SCS employees overlook recreation as a potential complementary land use. Take FSA, for example. Recreational hunting might be the most appropriate use on a specific area of Conservation Reserve Program (CRP) land. A water quality project will definitely benefit from improved fishing, better swimming and boating conditions, or other enhanced, water-related recreational, activities.

Incorporation of recreational activities into sustainable agriculture offers private landowners a unique opportunity to turn a marginal or failing operation into a profitable venture. There are many examples of successful operations across the country that take advantage of recreational opportunities. "U-pick" farms are one example. Urban residents pile into the family car for a leisurely drive into a rural setting to harvest their impression of the perfect edibles: peas, corn, strawberries, blueberries, cherries, water chestnuts, okra, tomatoes, etc. The producer complements this activity by providing a shaded picnic area where the family can round out the day's recreational experience.

A similar type of recreational opportunity is the "cut-your-own" Christmas tree farm. Again, urbanites head for the rural areas to select their concept of the perfect holiday tree: scotch pine, blue spruce, Douglas-fir, Noble fir, etc. All are accessible on foot or perhaps by a unique means of transportation, such as toy train, hay wagon, sled, or antique truck, to complete the recreational outing.

A fishing pond is a desirable land use. A small body of water in a picturesque setting is stocked with hungry trout, bass, catfish, or other suitable species. The kids twitch with excitement as their parents teach them the art of fishing while capturing all the memories on film.

Fee-hunting leases on part or all of a farm or ranch can be a suitable activity for many landowners. Today, this is one of the most profitable and environmentally compatible land uses. Fee leasing is rapidly growing in popularity as society accepts the concept of paying for hunting privileges. The hunting experience for big and small game, waterfowl, or upland birds is enhanced by proper habitat planning and management. Add to this setting a few rustic cabins for the hunters to spend their evenings impressing others with past hunting successes produces a total recreational experience.

These are just a few examples of relatively low-investment types of recreational activities that can be added to an existing farm enterprise. Additional recreational examples, such as campgrounds, vacation farms, dude ranches, bed and breakfasts, and places to purchase locally made crafts and prepared foods may require a slightly higher investment. The right recreational activity in the right location provides compatible, cost-effective, and sound stewardship uses associated with agricultural land. SCS specialists assist landowners in developing these creative recreational proposals while implementing not only sustainable agricultural systems, but all U.S. Department of Agriculture endeavors.—***Gary J. Jann, Soil Conservation Service, U.S. Department of Agriculture, Washington, D.C.***

Farm price distortions, chemical use, and the environment

By Clayton W. Ogg

CROP surpluses have constituted a persistent and conspicuous problem for U.S. agriculture. These surpluses appear to be particularly wasteful when they are caused by chemical inputs that pollute the environment. Past surpluses resulted in part from the encouragement of farm price support programs to increase application of chemicals and other nonland inputs. Initiatives during 1985 farm bill deliberations and, more recently, during negotiations under the General Agreement on Tariffs and Trade have focused on means to eliminate farm program influences on input use. More modest initiatives, undertaken in anticipation of the 1990 farm bill discussions, would reduce program influences over input use while preserving much of past price support program structures. The latter are stimulated partly by environmental and conservation concerns (*2, 7*).

Current programs and proposed policy options have several implications. Although some farm programs and water quality are in conflict, complementarities between farmers' goals and water quality also exist. Some options offered mainly to reduce price and resource use distortions could benefit both farmers and the environment.

The impacts of farm subsidies

Subsidies for a commodity or a production input raise profits, which can encourage firms to use more inputs, such as fertilizer or irrigation water, to produce more of the profitable commodity. U.S. farm commodity program payments have fostered chemical use in two ways. First, deficiency payments supported prices and raised the demand for chemicals to enhance base yields on farms.[1] Second, price supports encouraged base acreages (planted acreage recorded for some past period) of supported crops, such as corn and wheat, to expand relative to nonprogram crops, such as hay and soybeans, which happen to require less chemicals.

Maintenance of base acreages is frequently cited for supposed negative effects on crop rotations. But crop rotations involving corn and soybeans or hay can reduce soil erosion, and they allow farmers to virtually eliminate use of insecticides. Corn pests die during the year the other crops are rotated, and vice versa (*3*). Soybeans and legumes "fix" nitrogen in the soil, further reducing chemical needs. Farmers are said to maintain more continuous corn acreages, without rotations, anticipating that future programs may update the base acreage history (*7*).[2]

Acreage reduction programs counter base acreage expansions, as little chemical use occurs on set-aside acres. But acreage reductions ultimately add to price distortions by making less cropland available and bidding up land prices. Chemicals then are substituted for land, completely offsetting the chemical savings on idled land (*5*).

Incentives to use chemicals vary with each price support mechanism. For example, marketing quotas used in the past to support cotton, rice, and tobacco prices offer relatively little encouragement for more chemical use compared to the target price mechanisms described above. Farmers prefer to reduce variable production inputs, such as pesticides and fertilizer, rather than land, to meet quota limits on production. Set-asides of feed grain and wheat acreage, on the other hand, raise land values much more than quotas do, and fertilizer is a close substitute for land (*5*).

Even subsidized irrigation in the West encourages higher rates of fertilizer and pesticide application to complement heavier water use (*4*). Policies that create water markets or reduce water price distortions in other ways can conserve water as well as reduce pollution from chemicals.

Reducing deficiency payments

Reductions in subsidies may occur as a result of international trade negotiations or through unilateral modifications in farm programs. Reducing subsidies is one of several options likely to be discussed in the coming year as policymakers attempt to reduce price distortions and budget exposure.

Reducing target prices and deficiency payments for feed grains and wheat would have the largest direct impact on agriculture. Their magnitude (*8*) gives deficiency payments the greatest influence on acreage planted in these relatively chemical-intensive crops. Particularly in recent years, when nearly all larger producers of program crops have participated in programs, the base acreage incentive has provided direct program influence over land and chemical use.

Disaster relief payments also are tied to base yields, adding to resource use distortions from deficiency payments. Because of these potential input distortions, reducing deficiency and disaster subsidies would decrease U.S. agriculture's incentives to use more land and other inputs.

Reducing price or yield distortions

Price and chemical use distortions from program payments can be controlled even without reducing the payments themselves. Target price incentives to use more fertilizer, irrigation water, and other inputs (except land) stem from use of farm base yields as the basis for tying deficiency payments to recent production of a particular commodity. A number of options, such as continuing, indefinitely, the current freeze on each farm's base yield or using a national yield index to update each farm's yield history, would eliminate the use of recent farm yields in computing payments to farmers.

Commodity price distortions also could be eliminated for nonland inputs by using only average county yields to compute payments rather than allowing farmers to increase their farm's yield history or base yield above their neighbors' by applying more chemicals and other inputs. Farmers would henceforth have no incentive to increase their yields beyond levels suggested by world market prices, which in recent years have been 20 to 50 percent lower.

Since 1985, the United States has relied more on deficiency payments and export subsidies and avoided supporting the loan rate at levels that make U.S. goods uncompetitive. With world prices well below our target prices, price distortions could become substantial resource use considerations (*1*). For example, suppose grain producers expect their farms' base yields to be updated in future years and gear their

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[1]This is a delayed response because today's yields can affect payments only under future programs; the payments usually are based on a yield history from a designated past period, called the "base yield," times the base acreage, times the difference between current target prices and market prices.

[2]Dairy price supports, however, may have the opposite effect, as they encourage more livestock demand for hay crops, which are rotated with grains.

chemical use to the target price rather than to the world price. In this case they clearly would apply more fertilizer and pesticides. Their use of other nonland inputs, such as labor and machinery, also would increase. These incentives to increase input use raise the cost of controlling crop surpluses as well as add to chemical contamination worries.

Keeping the base yield frozen and related options reduce distortions in use of all the above inputs, but not land. Farmers would still maintain or expand base acreages to gain larger payments because base acreages are in the formula for computing target price payments, as are base yields. Other inputs complementary to land would still be affected indirectly by grain deficiency payments, but only from acreage expansion itself or through substitution of other production inputs for land. Recall that acreage set-asides are roughly neutral with respect to fertilizer use (*5*).

Reducing base acreage distortions

In spite of concern about input use distortions due to base acreage provisions, fewer options exist to operate price supports without farm base acreages than without farm-based yields. Elimination of the base acreage tool for tying payments to a commodity could eventually make payments function like income transfer (or welfare) programs because base acreages constitute the link between farm program subsidies and production activity.

Even if programs temporarily reduce restrictions on farmers' use of base acreages, some farmers may increase plantings to build up their base. For example, farm program rules introduced base acreage flexibility in the 1973-1980 period: Payments for wheat and feed grains were tied to a single, past year's plantings and yields of supported commodities, but virtually any use of base acreage was permitted and changing crops had no influence on yearly payments. In certain years, a portion of this old base acreage had to be idled, but the remaining acreage could be used for any crop or for no crop at all. Base yields also were tied to past yields.

Did this flexible system actually result in a decoupling of payments from planting decisions? The answer depends upon farmers' expectations. Those farmers who were shrewd or lucky enough to anticipate that the 1981 farm legislation would once again update base yields and base acreages likely maintained or increased base acreages and yields of feed grains, wheat, and cotton. Expansion in crop acreage of program crops continued in the late 1970s period even as market conditions began to deteriorate (*8*).

Can farmers be persuaded that future programs will not base payments on today's planting decisions? As cropping patterns shift, future farm bills clearly may again alter base acreages between states and between farms. Such uncertainties make it much more difficult to eliminate programs' land use or cropping pattern distortions compared to reducing other input use distortions caused by price supports.

Encouraging introduction of legumes and forage-based livestock activities by increasing base acreage flexibility appears to be especially difficult. Farmers have no assurance that future market conditions will not make them dependent again on programs.

Base acreage flexibility

The main environmental advantages that may result from base flexibility would stem from increased corn-soybean rotations in the Corn Belt. Although modeling farm program effects on crop rotations is difficult, the actual acreage shifts for soybeans in response to the major payment-in-kind (PIK) programs of the early 1980s can be examined, and the impacts on rotations involving soybeans inferred. Assume for the sake of analysis that base flexibility rules would be maintained permanently so that farmers cease to plant more program crops to build up their base.

Soybean plantings declined 7 million acres when major price support programs took effect in 1983 (*8*); the incentive to expand base acreages of feed grains could have caused this decline in soybean plantings. But the national decline in soybean acreages does not prove that base acreage provisions discourage crop rotations. Soybean acres declined with the reintroduction of major government involvement in agriculture in the first half of the 1980s. But the entire seven-million-acre reduction in soybean acreage between 1980 and 1985 occurred in southern states, where soybean acreages exceeded corn acreages.

Soybean acreage remained relatively unchanged in Corn Belt states, which need more soybeans for crop rotation with corn. Programs appear then to have little impact on this rotation crop in the Corn Belt and

Sorghum and soybean acreages in predominantly soybean-producing states, 1980 and 1985 (*8*)

State	Sorghum		Soybeans	
	1980	1985	1980	1985
	thousand acres			
Alabama	65	270	220	1,080
Arkansas	275	940	4,800	3,750
Delaware	NA	NA	265	245
Florida	NA	NA	475	260
Georgia	150	175	2,450	1,800
Kentucky	40	150	1,650	1,260
Louisiana	32	425	3,450	2,250
Maryland	NA	NA	400	410
Mississippi	75	650	4,000	2,700
Missouri	950	1,450	5,700	5,300
North Carolina	103	90	2,030	1,800
Oklahoma	700	580	350	210
South Carolina	30	80	1,700	1,290
Tennessee	55	480	2,650	1,500
Virginia	21	NA	620	720
Total	2,496	5,290	32,740	24,575

Corn and soybean planted acreages in predominantly corn-producing states, 1980 and 1985 (*8*)

State	Sorghum		Soybeans	
	1980	1985	1980	1985
	thousand acres			
Illinois	11,600	11,700	9,300	9,100
Indiana	6,300	5,450	4,400	4,500
Iowa	13,900	14,000	8,300	8,200
Kansas	1,300	1,700	1,550	1,500
Michigan	3,100	2,950	960	1,100
Minnesota	7,300	7,350	4,800	5,100
Nebraska	7,800	7,350	1,830	2,400
Ohio	4,250	4,150	3,800	3,900
South Dakota	780	1,280	3,480	3,510
Texas	1,550	1,500	700	320
Total	57,880	58,700	39,120	39,630

Water price and input use for surface water and groundwater users, 1982*

Water source	Water ($/acre-foot)	Fertilizer ($/acre)	Pesticides and herbicides ($/acre)	Energy ($/acre)	Machinery capital† ($/acre)	Hired labor ($/acre)	Water (Acre-foot/acre irrigated)	Irrigated (acre/farm)	Cropland (acre/farm)
Surface water only users‡	15	36	25	31	242	40	2.7	279	496
Groundwater users§	35	28	13	37	201	24	1.8	585	824

*Based on a sample of 547 farms growing only field crops (no livestock or specialty crops). All input use is for 1982, except water, which is for 1984. Primary data were from the 1982 Census and from a special 1984 Farm and Ranch Irrigation Survey *(7)*. I am indebted to the Agricultural Division, Bureau of the Census, for allowing use of the primary data, and to the Economic Research Service, U.S. Department of Agriculture. The sample design, data collection, and processing were conducted by the Bureau of the Census. I take sole responsibility for the analysis and results.
†Machinery represents a capital input, whereas all other inputs, except water, are expenditures for 1982.
‡Price and water use data are for off-farm surface water only.
§The water price used is the farmer's estimate of groundwater pumping cost/acre foot. (Some of these groundwater users also obtained surface water.)

apparently increased opportunities for soybean rotations with grain sorghum in the South. More sorghum reduces the need for chemically intensive soybean monoculture.

According to data from the Cost of Production Survey of the Economic Research Service, more than two-thirds of midwestern corn was grown in some type of rotation with soybeans. Base yield options (described earlier) may be much more of a chemical use consideration than base acreage effects on crop rotations.

Reduction in soybean acreage, however, may result from program rules that prohibit double-cropped soybeans on wheat set-asides *(6)*. Double-cropping may not greatly affect the need for insecticides, but it greatly reduces soil erosion compared with soybean monoculture. Double-cropping also reduces the need to apply nitrogen to the wheat crop.

Would soybean plantings rebound in the South under the base flexibility option, or would soybeans advance in the Corn Belt, expanding beyond the levels that existed prior to the 1983 PIK program? If the expansion occurs in the South, double-cropping will reduce soil erosion. If the adjustment occurs instead in the Corn Belt, corn-soybean rotations will likely increase and reduce chemical use.

In the long run, price supports also affect technology development and adoption by farmers. Research in the Palouse Region suggests that farmers might adopt a yearly wheat rotation with a legume called black medic. Black medic efficiently fixes nitrogen to the soil, eliminating the need for nitrogen fertilizer. In the absence of price supports,[3] or perhaps under the base flexibility option, such extensive agricultural technologies become suitable for educational programs. But the analysis suggests that developing flexible options capable of facilitating such long-run changes is particularly difficult.

[3]Young, D. L., and W. A. Goldstein. 1989. "How government programs discourage sustainable cropping systems: A U.S. case study." Paper presented at Farming Systems Research Symposium, Fayetteville, Ark.

Water subsidies

Just as supporting commodity prices encourages more chemical and other input use, subsidized prices for surface water used for irrigation are said to encourage more intensive use, not only of water, but also of fertilizer and other complementary inputs *(4)*. Surface water users, who pay less for water than do groundwater users, apply considerably more chemicals and other inputs to conventional field crops.

The 547 irrigated farms encompassed in the accompanying table were weighted by the Bureau of the Census to represent about 10,000 farms growing field crops, but no livestock or specialty crops, in the western states. This is a relatively homogeneous group of farms, drawn from the original 11,000 irrigated farms that responded to the survey *(9)*. Water prices and water use could account for the lower input use by groundwater irrigators, who receive lower subsidies than the surface water irrigators.

Once again, various options are proposed to make water prices reflect the true cost of water. Some options, such as raising the price irrigators pay for Bureau of Reclamation water, clearly would not benefit farmers.

Complementarities in farm policy

Policy options that reduce deficiency payments for farm commodities or reduce water subsidies are advocated for reasons of efficiency and budget limitations and to increase agricultural trade. Generally, lower subsidies also reduce economic pressures to apply chemicals and other inputs *(1)*.

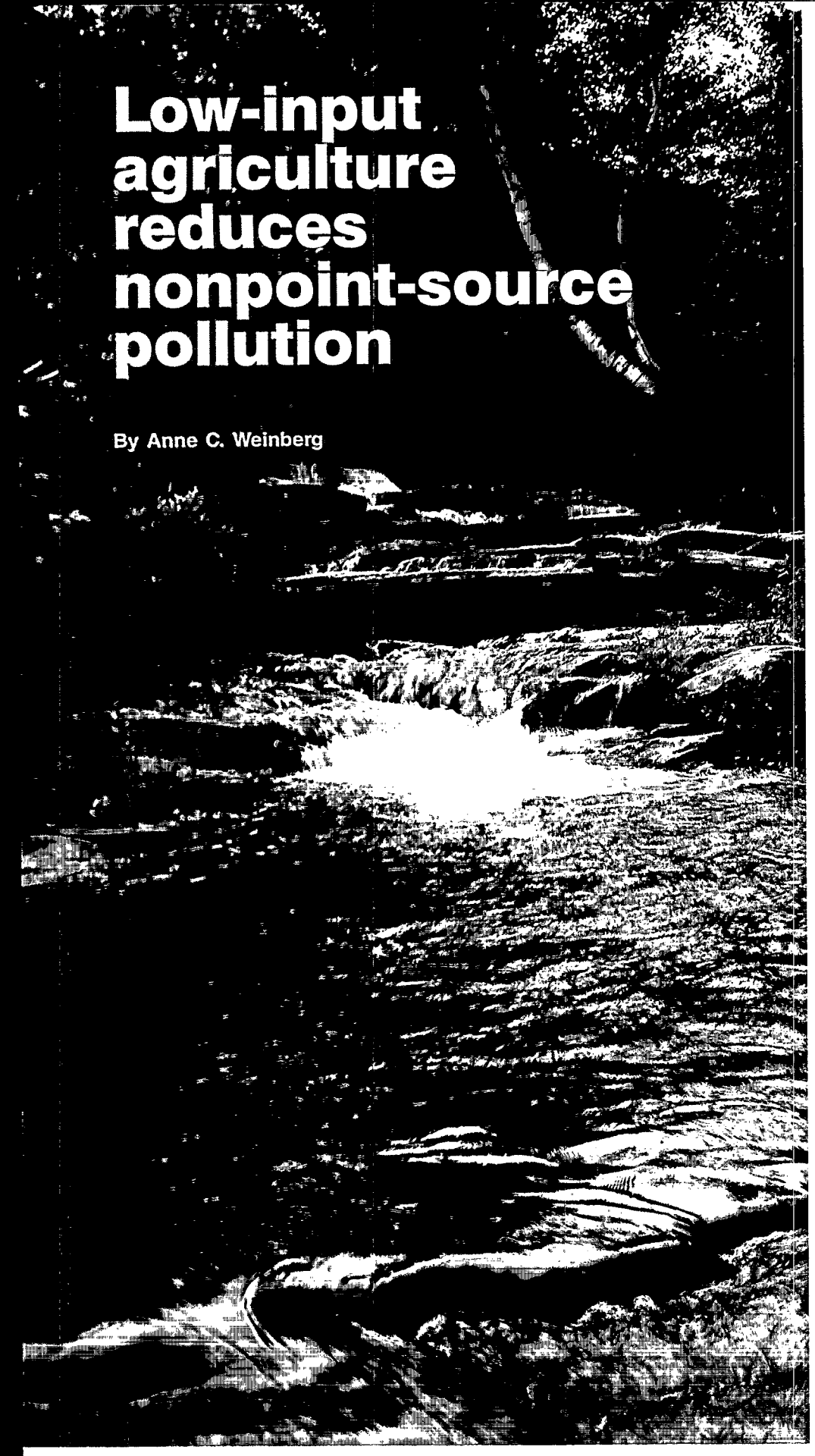
Virtual elimination of commodity price distortions that encourage chemical use also can accompany continuation of the current subsidy levels, so long as programs avoid creating incentives to increase farms' base yields. The reductions in chemical and other input applications benefit farmers, too, and taxpayers, because farm prices greatly affect farm production inputs, and price distortions aggravate crop surpluses. More flexible use of program acres could even allow programs to claim a net reduction in certain pollutants because acreage reductions likewise reduce chemical use. Markets for water rights would result, similarly, in water, fertilizer, and other input savings, and would benefit farmers through the sale of water rights to higher value uses.

REFERENCES CITED

1. Ball, V. E. 1988. *Modeling supply response in a multiproduct framework.* Am. J. Agr. Econ. 70(4): 813-825.
2. Batie, S. 1988. *Agriculture as the problem: New agendas and new opportunities.* S. J. Agr. Econ. 20(1): 1-12.
3. Center for Agriculture and Rural Development. 1988. *Corn root worm analysis: An application of CEEPS.* Iowa State Univ., Ames.
4. Frederic, K. D. 1986. *Irrigated agriculture and mineralized water: Comment and discussion.* In T. T. Phipps, P. R. Crosson, and K. A. Price [eds.] *Agriculture and the Environment.* Resources for the Future, Washington, D.C.
5. Hertel, T. W. 1988. *Changing the level and mix of subsidies to agriculture: Implications for output, exports, employment, and factor returns.* Staff Paper 88-2. Dept. Agr. Econ., Purdue Univ., West Lafayette, Ind.
6. Holloway, H. 1989. *A mixed integer programming model for analysis of impact of conservation compliance.* M.S. thesis. N. Car. State Univ., Raleigh.
7. Reichelderfer, K., and T. T. Phipps. 1988. *Agricultural policy and environmental quality.* Center for Food and Agricultural Policy, Resources for the Future, Washington, D.C.
8. U.S. Department of Agriculture. Various issues. *Agricultural statistics.* Washington, D.C.
9. U.S. Department of Commerce. 1986. *1984 farm and ranch irrigation survey.* Rpt. AG-84-SR-1. Bur. Census, Washington, D.C. □

Low-input agriculture reduces nonpoint-source pollution

By Anne C. Weinberg



DESPITE progress, agriculture continues to impose stress on the environment. Much of agriculture's emphasis in the past focused on increasing output, such as yield. Now, emphasis needs to be put on what Odum terms "input management" (*2*). The way to reduce nonpoint-source pollution, he suggests, is to manage inputs more efficiently—not just for agricultural systems, but for all production systems. Reduced-tillage cropping systems and improved pesticide and nutrient management are examples of low-input practices that reduce unwanted outputs. State nonpoint-source management programs are a primary vehicle for promoting the use of low-input agricultural approaches.

Consequences of high inputs

Groundwater pollution is emerging as a central issue. At present, the extent of pesticide contamination of groundwater cannot be determined (*3*). The U.S. Environmental Protection Agency (EPA) has a national pesticide survey underway. It is the first nationwide investigation of pesticide contamination of drinking water wells. This survey involves sampling of both domestic and community wells for more than 70 pesticides and for nitrates. The survey should produce the first nationally consistent data to support EPA decision-making. The final survey report is due in the fall of 1990.

In addition to that survey, EPA compiles summaries of pesticides found in groundwater due to normal applications to the land that are reported by various states where monitoring has occurred. In 1984, 12 pesticides were found in groundwater as a result of normal applications in 18 states (*3*). By 1985, 17 pesticides had been detected in 23 states (*3*). In December 1988, EPA released an interim report on pesticide detections in groundwater indicating that normal agricultural use apparently had led to residues of 46 different pesticides in groundwater in 26 states (*7*). Additional monitoring will likely reveal more locations where pesticides have entered groundwater.

Groundwater monitoring over the past decade also indicates a growing problem of contamination from agricultural use of nitrate fertilizers. According to another EPA report (*4*), the frequency and levels of nitrate contamination in water wells increased in

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nearly every state between 1970 and 1985. This review and other studies indicate a direct relationship between nitrate leaching to groundwater and nitrogen fertilizer use rates.

According to a 1986 national assessment of surface waters (*5*), nonpoint-source pollution is the most pervasive and among the most serious water quality problems remaining in the United States. Agricultural runoff was by far the most common cause of nonpoint-source pollution in both lakes and streams reported by the states in 1986. Of the assessed waters impaired or threatened by nonpoint sources, agricultural activities were a major cause in 64 percent of the nation's rivers and streams and 57 percent of the lakes (*5*).

The nonpoint-source problems in surface waters due to agriculture can be illustrated by the experiences in Chesapeake Bay. EPA's 1983 study of the Chesapeake Bay found nonpoint sources of pollution among the chief causes of the bay's decline (*10*). Based on an extensive modelling effort concluded in 1983, EPA estimated that in an average year nonpoint sources contributed 67 percent of the nitrogen and 39 percent of the phosphorus that were entering the bay. Point sources were found to contribute the differences: 33 percent of nitrogen and 61 percent of phosphorus.

Runoff from cropland contributed the largest estimated share of the nonpoint-source nutrient load to Chesapeake Bay (*10*). While farming has occurred around the bay for more than 300 years, significant changes in farming methods have occurred in the last 40 years, altering the impacts on the bay. In the Chesapeake Basin, cropland declined 24 percent between 1950 and 1980 (*8*). The resulting intensification of agricultural activity, that is growing more on less land in the basin, has led to a major increase in the use of fertilizers and other chemicals inputs (*9*). In addition, the consolidation of agricultural land into fewer and larger farms, owned by absentee landlords or corporations and operated by tenants, may reduce the incentive to control soil and chemical loss.

Section 319 programs

The most recent national legislative response to these nonpoint-source pollution problems is Section 319 of the Water Quality Act of 1987. Under this section, each state *had to develop and submit for EPA approval* a nonpoint-source assessment report and management program by August 4, 1988. EPA then reviewed and approved the state submissions and allowed states additional, limited time to revise and resubmit reports or programs that were not approved initially.

The contents of both the assessment report and the management program are listed in detail in Section 319 of the Clean Water Act, as amended. Briefly, the assessment report must identify (a) the navigable waters within the state that will not attain or maintain water quality standards or the goals and objectives of the act without additional action to control nonpoint sources, (b) the categories of nonpoint sources responsible for the water quality problems, (c) the process the state has used to identify the best management practices to control nonpoint sources, and (d) the state and local programs available to address the identified problems.

The nonpoint-source management program is a plan for what the state intends to do over the next four years to begin addressing nonpoint-source problems identified in the assessment report. The management program must include (a) the best manage-

HOW LOW-INPUT AGRICULTURE CAN HELP MAINTAIN WATER QUALITY

Farmers and rural communities alike are significantly affected by the contamination of surface water and groundwater supplies. Half of the population in the United States depends upon groundwater for its drinking water. In Iowa and Nebraska, 86 percent of the population relies on groundwater for its water supplies, as do 75 percent of the people in Kansas. Virtually all of the water farmers use comes from the ground without any treatment. Most rural communities do not have water treatment systems, either.

Agricultural chemicals are the greatest, uncontrolled threat in the United States to surface water and groundwater quality. Most of the problems are because of the large number of acres devoted to agricultural production.

In the past, the U.S. Environmental Protection Agency (EPA) focused its programs on controlling point sources of pollution. Recently, the agency began emphasizing more programs on nonpoint-source pollution problems, namely, agricultural chemical runoff. Every state in the United States has since developed a nonpoint-source management plan, with a central focus on groundwater in rural areas.

Three of EPA's initiatives to address problems from agricultural chemical pollution include the following:

► *The National Pesticide Survey,* an attempt by EPA to determine the levels of pesticides in groundwater throughout the United States. The program involves testing 1,500 wells, 750 private wells, and 750 public water systems. Initial results are to be released this spring.

► *The Pesticide and Groundwater Strategy,* previously titled the Agricultural Chemical Strategy, is a program in which states are encouraged to develop plans to identify those areas where specific pesticides can or cannot be used. If states do not develop plans, then EPA's overall plan will come into effect. Essentially, EPA's plan would be more stringent than a state's tailored plan for site-specific conditions.

► *The Wellhead Protection Program* also encourages states to develop programs for local communities to protect areas surrounding their well or wellfield. Under the guidance of a state plan, communities can develop individual plans to control potential groundwater contamination activities within their designated wellhead area.

EPA also has been emphasizing proper disposal of pesticide containers. Guidelines are outlined on the label that accompanies every pesticide sold. However, some problems do occur. For example, if a requirement calls for disposing of cans in a sanitary landfill that is a long distance from the application site, farmers may not voluntarily comply. In fact, because farmers need water to mix with pesticides in the sprayer, often, empty cans are stacked around the well—the same well that supplies untreated drinking water to farm families and livestock.

Education is needed now more than ever to explain to farmers the dangers of using chemicals and the importance of proper disposal. Farmers already know that agricultural chemicals pose a threat to their health and to the environment. What they don't know is how to stop using them without affecting farm profitability.

In the future, we will see:

► More biotechnologies and natural pesticides, such as crop rotations.

► More prescriptive use of pesticides. The labels will contain additional restrictions, such as where, when, and how the pesticides can be used.

► More emphasis within EPA on water quality problems caused by agriculture and silviculture. Agriculture and silviculture combined account for more than 80 percent of land use in America.

► More coordination and cooperation between the U.S. Department of Agriculture and EPA to create complementary programs to protect surface water and groundwater.

► Some form of a monetary deposit placed on agricultural chemical containers, with chemical dealers playing an important role in recycling.—***Robert Fenemore,*** *Office of Groundwater Protection, U.S. Environmental Protection Agency, Kansas City, Kansas, speaking at "The Promise of Low-Input Agriculture" conference.*

ment practices (BMPs) that the state plans to use to reduce nonpoint-source pollution, (b) a summary of the state's nonpoint-source implementation programs, (c) a schedule of annual milestones for the next four years, (d) a certification by the state attorney general that the laws of the state are adequate to implement the management program, (e) sources of funding to implement the program, and (f) federal financial assistance programs and development projects that the state will review for consistency with its management program, referred to as the federal consistency provision.

While the emphasis in Section 319 is on surface water, EPA guidance (*6*) encouraged states also to identify any known or suspected groundwater problems caused by nonpoint sources in their assessment reports.

While EPA was disappointed that more states did not meet the initial reporting deadline of August 4, 1988, most states are making substantial progress in meeting the requirements of Section 319. As of mid-February 1990, EPA had approved 55 final assessment reports. Also as of that date, EPA had approved 54 management programs—either portions of programs or complete management programs.

Nonpoint-source management programs provide an opportunity for states to promote use of low-input agricultural approaches. While there is no comprehensive summary of the contents of all state programs, reviews of selected states indicate that many are promoting such approaches in their nonpoint-source management programs. For example, Virginia as well as other Chesapeake Bay states have instituted nutrient management programs as part of their bay cleanup efforts, and these are reflected in their management programs.

Funding for state programs

The Water Quality Act of 1987 also provides a variety of funding sources for implementing state management programs. These funding sources may be used to promote low-input agricultural practices, among other activities. Funding sources include:

► Section 205(j)(5), which is a set-aside of up to one percent of each state's construction grant allotment or a minimum of $100,000. Funds may be used for both developing and implementing nonpoint-source assessment reports and management programs.

► Section 319(h) authorized $400 million in fiscal years 1988 to 1991 for implementing state management programs. Congress appropriated $40 million in fiscal year 1990.

► Section 319(i) authorized up to $7.5 million annually of the Section 319 total for any groundwater protection activities that will advance states toward implementation of comprehensive nonpoint-source control programs. Targets for groundwater activities will be established as part of Section 319(h) grant awards in fiscal year 1990.

► Section 201(g)(1)(B) authorized states to use up to 20 percent of their construction grant allotment to implement their management programs. Delaware, South Dakota, and other states have used these funds.

► Section 603(c)(2) allows states to use their state revolving funds to implement their management programs. These funds may provide an important source of nonpoint-source implementation funds in the future as point-source controls needs are met.

► Section 604(b) is a water quality management planning reserve attached to the state revolving funds that can be used in support of nonpoint-source and other planning activities.

In addition, EPA has encouraged states to use their own resources and to leverage the resources and authorities of other federal agencies to help accomplish nonpoint-source program objectives. One example of these opportunities is the Conservation Reserve Program (CRP) established by the Food Security Act of 1985, under which highly erodible land is retired from crop production. The CRP effectively reduces soil erosion, and EPA continues to work with the U.S. Department of Agriculture (USDA) to increase the program's water quality benefits. A positive step in this direction was USDA's decision to include filter strips along waterways among the acres eligible for CRP enrollment.

Best management practices

While states were to identify the overall dimensions of their nonpoint-source water quality problems in their assessment reports, EPA's Section 319 guidance encouraged states to carve out a subset of these waters in their state management programs for concerted action on a watershed-by-watershed basis over the next four years. The rationale for this is that targeting implementation activities to particular geographic areas provides the greatest opportunity for achieving visible water quality improvements in the short run (*1*). In addition, the Section 319 guidance encouraged states to develop statewide program approaches to address such nonpoint-source problems as construction erosion, urban stormwater runoff from developing areas, and forestry practices. States may promote use of low-input agricultural approaches as part of targeted watershed projects as well as part of statewide or regional education programs.

States will be identifying the best management practices (BMPs) that they will be using in the implementation of their management programs. States continue to implement traditional soil and water conservation practices as well as other approaches, such as integrated pest management and nutrient management. The emphasis in traditional soil and water conservation programs has been on the installation of structural BMPs, such as terraces, grassed waterways, and animal waste storage facilities. These practices have the greatest impact on sediment and sediment-associated pollutants in surface runoff. Reducing sediment and associated pollutant loadings in surface waters are appropriate water quality objectives in many watersheds.

Increasingly, soil and water conservation agencies are also recognizing the importance of reducing the input of pesticides and fertilizers to groundwater. Source controls, such as restricting or banning use of pesticides in areas vulnerable to groundwater contamination, is an effective approach. Nutrient application rates also may be restricted. Other land management practices, such as modifying application methods for animal waste; irrigation scheduling to minimize water use, surface runoff, and leaching; and conservation tillage can minimize loss of pollutants to surface and groundwater. As emphasized above, these types of low-input agricultural approaches hold the promise of reducing unwanted outputs and, hence, reducing nonpoint-source pollution.

REFERENCES CITED

1. Maas, R. P., M. D. Smolen, C. A. Jamieson, and A. C. Weinberg. 1987. *Setting priorities: The key to nonpoint source control.* U.S. Environ. Protection Agency, Washington, D.C.
2. Odum, E. P. 1989. *Input management of production systems.* Science 243: 177-182.
3. U.S. Environmental Protection Agency. 1986. *Pesticides in ground water background document.* Off. Ground-Water Protection, Washington, D.C.
4. U.S. Environmental Protection Agency. 1987. *Draft report: Assessment of nitrogen fertilizer use on ground water nitrate levels.* Off. Toxic Substances, Washington, D.C.
5. U.S. Environmental Protection Agency. 1987. *National water quality inventory: 1986 report to Congress.* Off. Water, Washington, D.C.
6. U.S. Environmental Protection Agency. 1987. *Nonpoint source guidance.* Off. Water Regulations and Standards, Washington, D.C.
7. U.S. Environmental Protection Agency. 1988. *EPA issues interim report of pesticide detections in groundwater.* Press release, Dec. 13. Washington, D.C.
8. U.S. Environmental Protection Agency, Region 3. 1983. *Chesapeake Bay: A framework for action.* Annapolis, Md.
9. U.S. Environmental Protection Agency, Region 3. 1983. *Chesapeake Bay program: Findings and recommendations.* Philadelphia, Pa.
10. U.S. Environmental Protection Agency, Region 3. 1988. *Chesapeake Bay nonpoint source programs.* Annapolis, Md. □

Research on alternative farming systems and alternative chemical management should aid in the search for ecological sustainability

Soil Conservation Service

By Richard Lowrance

Research approaches for ecological sustainability

SUSTAINABLE agriculture is an objective often used as shorthand for a particular set of practices. Because of the confusion engendered by various uses of the term "sustainable" and because of the various components of the food and agricultural system upon which people focus, sustainability has numerous competing meanings, including "sustainability as food sufficiency," "sustainability as stewardship," and "sustainability as community" (*1, 2, 3*). These three views were integrated into a hierarchical view by defining the various sustainability objectives that are necessary within modern agricultural systems (*6*). These sustainability objectives can be described as:

- *Agronomic sustainability*—the ability of a tract of land to maintain productivity over a long period.
- *Microeconomic sustainability*—the ability of a farm to stay in business as the basic economic unit.
- *Ecological sustainability*—the ability of life support systems to maintain the quality of the environment.
- *Macroeconomic sustainability*—the ability of national production systems to compete in both domestic and foreign markets.

Ecological sustainability is a necessary condition to achieve long-term sustainability at the field, farm, or national level. Degradation of environmental quality through management practices that pollute soil, water, and air precludes the ecological sustainability of a landscape or regional agricultural system. Historically, the farm bills passed before 1985 had few, if any, provisions to promote ecological sustainability; these bills focused on farm income objectives and on enhancing international trade.

The sodbuster, swampbuster, and conservation compliance provisions of the 1985 Food Security Act are widely recognized as providing a landmark link between farm income support programs (largely to achieve microeconomic sustainability) and environmental quality protection (to achieve ecological sustainability). In addition, expansion of the Conservation Reserve Program to make buffer strips eligible for enrollment represented an explicit attempt to provide financial incentives to improve water quality.

The debate forming around the next farm bill promises to lead to more provisions to achieve ecological sustainability, especially relative to water quality. Although water

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quality is just one factor in determining ecological sustainability, both Congress and the executive branch have proposed various initiatives to address water quality degradation resulting from agriculture.

One of the proposals to improve water quality is to provide incentives for and remove barriers against low-input farm management (*4*). This approach has been embodied in S.970, introduced by Senator Wyche Fowler (D-Ga.) and others. Among other things, this bill would allow farmers who attempt the transition to low-input management to maintain their commodity crop base acreage. In addition, the bill provides financial incentives and technical assistance for application of low-input techniques.

Many observers believe that provisions of this sort will be included in the next farm bill. Successful implementation of this program will require a new commitment to develop farming systems that are sustainable at the field, farm, ecosystem, and national levels. Development of these production systems will require a novel approach to agricultural research in the United States.

An optimistic view

Increasing public concern over environmental quality has not yet been translated into substantive changes in agricultural practices. The special status of agriculture as an industry—the only industry that produces the food we eat—has provided an extraordinary level of support for agriculture in the past. Possibly, the special status given to agriculture will mean that the public will hold agriculture, as an industry, to higher standards of environmental quality and safety than other industries. The future for U.S. farming will require considerably more emphasis on environmental quality. This trend is already apparent in parts of the country where environmental quality, particularly water quality, has been most degraded by agriculture.

Most farmers and other agricultural professionals think that the agricultural community can solve its own problems related to environmental quality. Solving these problems means that farming practices will be modified so that the general public will have confidence in farmers' ability to produce safe, abundant food without adverse effects on the environment. People in the agricultural community would generally agree that eliminating general environmental degradation from farming practices will come about by redirecting part of the present system of research, education, extension, technical assistance, and financial incentives. If the public loses confidence in the ability of this system to solve agriculture's environmental quality problems, the nation will turn to regulatory approaches that may impose management practices without adequate knowledge of their effects on all levels of sustainability.

Two approaches

Ecological sustainability relative to water quality will be attained by reducing the chemical outputs from field-scale systems to the environment. In this context, sustainable production systems can be viewed as a set of alternative techniques that, among other things, reduce these chemical outputs to levels that society deems acceptable. Two general approaches can be applied to achieve ecological sustainability: *alternative farming systems* and *alternative chemical management.*

The alternative farming systems approach can be characterized by:

- ► Reduced reliance on, or elimination of, chemicals for pest control and chemical fertilizer for nitrogen management.
- ► Increased reliance on legumes, cover crops, crop rotations, and animal manures for fertility management.
- ► Increased reliance on crop rotations, tillage, cover crops, biological control, and resistant varieties for control of insects, nematodes, diseases, and weeds.
- ► A shift to alternative crops when previous management systems are unsuccessful for agronomic goals or environmental protection.
- ► Selection of crops based on market conditions, rotation requirements, land capabilities, and pest pressures.

The alternative chemical management approach can be characterized by:

- ► Continued reliance on chemicals for pest control and fertilizer for nitrogen management.
- ► Applications of chemicals based on more precise calculations of need and timing of need.
- ► Reliance on the development of new technologies for chemical application to retain hydrologically active chemicals in the root zone.
- ► A shift to alternative chemicals when management of previous chemicals is unsuccessful for agronomic goals or environmental protection.
- ► Selection of crops based on commodity programs, market conditions, and availability of chemical technologies.

Neither approach implies a level of technological sophistication, a scale of farm size, or a value judgment relative to the desirability of either approach. Although the two approaches are not mutually exclusive, they are accurate descriptions of many research programs that eventually will be translated into management recommendations.

Certain aspects of the two approaches may be difficult to integrate; for example, late-season herbicide use for weed control and relay cropping of herbicide-sensitive crops might be incompatible. Farmers may eventually adapt certain practices from both systems to meet their needs, or they may opt for approaches that largely fit the general descriptions outlined. Either approach can be integrated with off-field control pollution measures, such as vegetated filter strips, surface detention, or streamside buffers.

New research

The alternative farming systems and the alternative chemical management approaches are not well integrated and have not been applied comprehensively to the problems of water quality degradation from agriculture. Two new research initiatives relevant to these approaches are the U.S. Department of Agriculture low-input/sustainable agriculture (LISA) grants program and the USDA water quality research initiative. The LISA program is the result of the Agriculture Productivity Act, passed as part of the Food Security Act of 1985. The Agriculture Productivity Act will be considered for reauthorization in the next comprehensive farm bill. Congress appropriated $3.9 million for LISA in fiscal year 1988 and $4.5 million in fiscal year 1989.

The USDA water quality research plan is part of an interagency/interdepartment initiative by the Bush Administration, which proposed to allocate $58.6 million in new water quality funding for fiscal year 1990, with about 80 percent ($46.5 million) to fund USDA programs. Congress provided $14.6 million of new funding for fiscal year 1990 for research by three agencies: Agricultural Research Service (ARS—$7.5 million), Cooperative State Research Service (CSRS—$5.3 million), and Economic Research Service (ERS—$1.8 million). This represents an increase of about 30 percent in the research budget for water quality in these three agencies overall.

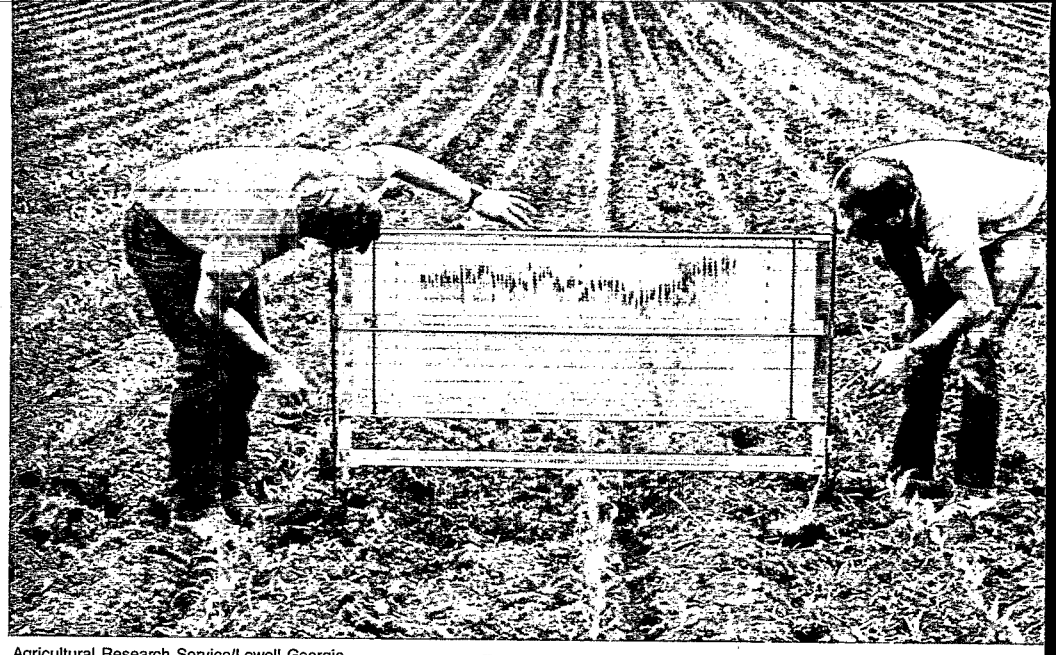
The guiding principles for the LISA program are ecological, agronomic, and economic sustainability. These goals will be achieved by substituting skilled management, on-farm resources, and biological resources for purchased chemical and nonbiological inputs from off-farm sources. While reducing impacts on water quality is important to LISA concepts, the program is concerned with the full range of potential threats to ecological sustainability (*9*) (Neil Schaller, personal communication, 1989).

Low-input, sustainable systems will have the greatest positive impact on environmental quality if chemicals that cause water quality problems are reduced or eliminated. In the case of fertilizers, we cannot change the fact that two of the essential plant macronutrients, nitrogen and phosphorus, can cause environmental quality problems in either surface water or groundwater or both. Crop production systems must provide these nutrients in relatively large amounts, and systems that provide them without commercial fertilizers are not necessarily environmentally benign. For instance, providing nitrogen from manure application can cause excess, leachable nitrate in the soil profile. Legume cover crops have the potential to cause nitrate leaching if nitrogen mineralization is not synchronized with nitrogen uptake by the crop plant. Research to understand the environmental quality effects of various plant nutrition schemes and to design plant nutrition systems to enhance both ecological and microeconomic sustainability should be a part of LISA.

Whether alternative farming systems contribute to improved environmental quality by reducing pesticide use depends upon the specific chemical in question. Some pesticides are very unlikely to create environmental quality impacts due to field use. If research on alternative farming systems leads to reduction or elimination of the use of pesticides that are not responsible for groundwater or surface water contamination, environmental quality will not be improved. Other sustainability objectives at the agronomic or microeconomic level might be met or soil quality might be improved, but unless research is focused on problem pesticides, environmental quality improvements will not result from the new production systems.

On the other hand, the USDA research plan for water quality (*10*) emphasizes the alternative chemical management approach as the primary means to achieve improvements in environmental quality. Emphasis on controlled-release formulations of pesticides, chemigation, and fertigation and a major focus on the fate of agricultural chemicals indicate that this approach is dominant, although not exclusive. Understanding how to manage today's chemicals in today's production systems should lead to short-term benefits.

The problem is that alternative farming systems research is not being emphasized as the long-term solution. Alternative farming systems approaches will be less likely to neglect other sustainability goals and the relevant side effects. USDA, especially ARS, has a pivotal role to play in bringing the systems approach to bear on environmental quality problems.



Agricultural Research Service/Lowell Georgia

Researchers use a needle gauge to study surface roughness on fields of ridge-till pioneer Dick Thompson of Boone, Iowa.

Research approaches

The 1990 farm bill will probably provide for increased incentives to reduce agricultural impacts on environmental quality. Groundwater has been of particular concern, and legislation may include provisions that link the finding of contaminated groundwater to incentives or requirements to apply low-input agronomic techniques. This approach runs ahead of the present state of scientific knowledge and will compel the scientific community to develop appropriate techniques quickly and efficiently. Generally stated, the level of scientific knowledge is that we do not know how certain alternative management practices will affect environmental quality. This is especially true for alternative farming systems that might be applied to improve environmental quality. In addition, we also do not always know how the alternative approaches will affect microeconomic sustainability, the ability of farms to stay in business. All of these unknowns are arguments for committing substantial resources to the alternative farming systems approach.

Understanding how alternative management systems can affect sustainability on different levels is urgent because of the nature of natural systems and political systems alike. Environmental contamination from agriculture, especially groundwater contamination, will take years to reverse. One reason that groundwater was in the past thought to be impervious to contamination was that travel times for contaminants from the soil surface to deeper aquifers can be 20 to 40 years (*5, 8*).

Political pressures may be even more compelling. The Environmental Protection Agency (EPA) is waiting to see if the traditional research/extension/technology transfer approach will work to improve environmental quality as it has worked to raise productivity. Without rapid progress in solving these problems, public opinion, through congressional action, will likely push EPA into regulating the management practices available to farmers.

A research framework

USDA is not alone in attempting to develop farming systems that cause minimal environmental damage. Farmers, land grant universities, private institutions, state departments of agriculture and natural resources, the U.S. Environmental Protection Agency (EPA), and the U.S. Geological Survey (USGS) all have critical roles to play. I would like to propose an interdepartmental framework that would use the expertise of farmers, federal and state agencies, and business and interest groups to bring about the research needed to solve the problem.

I envision a research effort guided by assessment of the problem areas in groundwater and surface water contamination. The assessment of chemical risks and the assessment of vulnerable aquifers and surface waters would be carried out by EPA, USGS, and appropriate state agencies. The risk assessments and the aquifer and surface water assessments would help to focus research by the agricultural community on the problem chemicals and on the problem areas of the country. In addition, EPA and state environmental protection agencies will have the ultimate responsibility to determine

whether water quality standards are being met by agricultural practices, particularly alternative chemical management practices.

ARS and the state land grant institutions will interact in pursuing the alternative farming systems approaches and the alternative chemical management approaches. These research organizations can play specific roles in both of these approaches.

The land grant institutions are well suited to develop production systems designed specifically for individual natural resource systems. Land grant institutions usually derive a portion of their research support from public sources and a smaller but vital portion from chemical companies and commodity groups. In general, future public monies should be focused to develop specific alternative farming systems that contribute to long-term sustainability and possess the characteristics described here.

Conversely, research on alternative chemical management for specific commodities should be funded largely by the ultimate beneficiaries of the research. These beneficiaries are primarily the chemical manufacturers that want to continue marketing existing chemicals and the commodity groups that have a substantial interest in maintaining today's cropping systems. The alternative chemical management research can provide the basis for maintaining the economic interests represented by chemical manufacturers and dealers and commodity groups.

Land grant programs have to interact with appropriate farm-scale economics programs to determine the costs and benefits of specific alternative farming systems. Quantifying the economic value of environmental benefits will be critical if farmers are going to be offered financial incentives to improve off-farm environmental quality.

In general, ARS gets 100 percent of its funding from public sources and, therefore, is well suited to pursue research that will reduce overall chemical use and lead to changes in the mix of crops grown. Unlike the land grant institutions, ARS is not institutionally equipped to develop specific production systems for individual natural resource areas. The mission of ARS has been defined repeatedly as research that has both national interest and widespread applicability.

The most appropriate areas for ARS relative to the two approaches discussed here are to determine rates and pathways of basic processes related to plant nutrition and pest control or suppression and to develop models that incorporate this information about basic processes. This research is likely to have a more long-term and interdisciplinary emphasis. These are the types of research questions that ARS rightfully takes pride in tackling. In addition, the national mission and organization of ARS will be useful in determining the ability of chemical management approaches to meet national water quality standards.

Cooperative Extension and USDA's Soil Conservation Service (SCS) traditionally have maintained an informal division in technology transfer. Farmers traditionally sought Extension Service advice to address problems of animal and plant production, while SCS advice and assistance was oriented more toward soil conservation. As water quality becomes a major concern in agricultural landscapes, both Extension and SCS are finding increased demands from farmers and policymakers. Research in both areas described should provide information for these technology transfer activities.

Farmers have a critical role to play in both the design and the adoption of these new systems. Farmers who are willing to experiment with reduced-input practices have been successful in establishing farm systems that work agronomically and economically. In any region farmers have a wide ranges of abilities and resources. Farmers with the most resources and abilities will lead, but other farmers will need help from public outreach and education to be able to follow.

The success of on-farm research by innovative farmers or by innovative institutions, such as the Rodale Research Center, points out the need for farm-scale research on farm systems. Inadequate support for farm systems research has been identified as a major problem for the extension system (7). The farm is the level at which microeconomic sustainability must be evaluated. As alternative farming systems begin to depend on fewer purchased inputs and more management skill and manipulation of biological opportunities, the importance of farm-scale research will increase.

The combination of increasing interest among farmers for technology transfer related to ecological sustainability and increased need for on-farm and farm-scale research will put both research and extension personnel in a new and potentially exciting working relationship with farmers. Farmers who have successful alternative systems may want to know why they work—as will research and extension scientists. Understanding farmer-initiated advances and transferring the information to other farmers will be an important role for research and extension personnel at land-grant institutions.

Counter to prevailing notions

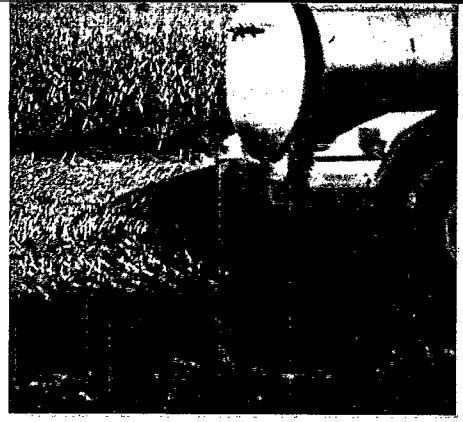
The proposals herein may run counter to a number of prevailing notions in the agriculture research community. First, it is true that the alternative chemical management and the alternative farming systems approaches overlap, and the distinction between them can be blurred. I think the distinctions are important (a) to help focus the alternative farming systems research on ecological sustainability, particularly water quality, and (b) to make it clear that keeping chemicals in the root zone is only one approach to improving water quality. Improved chemical management systems can be seen as the short-term approach to water quality problems, and the farming systems approach can be seen as the long-term solution.

Second, I recognize that suggesting roles for EPA, USGS, USDA, land grant institutions, and farmers is only a paper solution. Working together to solve the problems will take cooperation at all levels. Nevertheless, a model for interaction is needed, and these ideas can help provide the roots of that model.

Third, I recognize that the distinction between state and federal research roles is not a strict dichotomy. If nothing else, the successful interagency work that proceeds at experiment stations and universities means that neither federal nor state research will be exclusively in one area. Yet, the strengths identified for each research establishment appear to be real, and I believe the proposed emphasis for each should be considered when research policy is being set.

REFERENCES CITED

1. Berry, W. 1984. *The agricultural crisis as a crisis of community.* In G. K. Douglas [ed.] *Agricultural Sustainability in a Changing World Order.* Westview Press, Boulder, Colo. pp. 219-226.
2. Brown, G. E., Jr. 1984. *Stewardship in agriculture.* In G. K. Douglas [ed.] *Agricultural Sustainability in a Changing World Order.* Westview Press, Boulder, Colo. pp. 147-158.
3. Douglas, G. K. 1984. *The meanings of agricultural sustainability.* In G. K. Douglas [ed.] *Agricultural Sustainability in a Changing World Order.* Westview Press, Boulder, Colo. pp. 3-30.
4. Fleming, M. H. 1987. *Agricultural chemicals in ground water: Preventing contamination by removing barriers against low-input farm management.* Am. J. Alternative Agr. 2: 124-130.
5. Hallberg, G. R. 1986. *Agrichemicals and water quality.* Colloquim on Agrichemical Management and Water Quality. Board on Agr., Nat. Acad. Sci./Nat.Res. Council, Washington, D.C.
6. Lowrance, R., P. F. Hendrix, and E. P. Odum. 1986. *A hierarchical approach to sustainable agriculture.* Am. J. Alternative Agr. 1: 169-173.
7. National Research Council. 1989. *Alternative agriculture.* Nat. Acad. Press, Washington, D.C.
8. Ronen, P., Y. Knafi, and M. Magaritz. 1984. *Nitrogen presence in groundwater as affected by the unsaturated zone.* In B. Yaron, G. Dagan, and J. Goldschmid [eds.] *Pollutants in Porous Media.* Ecolog. Studies No. 47. Springer-Verlag, New York. N.Y. pp. 223-236.
9. U.S. Department of Agriculture. 1988. *Low-input/sustainable agriculture: Research and education program.* Coop. State Res. Serv. and Extension Serv., Washington, D.C.
10. U.S. Department of Agriculture. 1989. *USDA research plan for water quality.* U.S. Gov. Print. Off., Washington, D.C. □



SPECIFICITY
The context of research for sustainability

By D. T. Walters, D. A. Mortensen, C. A. Francis, R. W. Elmore, and J. W. King

THE information required for specific decision-making processes in agriculture is requested by a variety of clientele, including congressional committees, environmental groups, and private industry representatives, as well as individual agricultural producers. The information requested should provide the client with a probability of success (usually economic) of performing a given management practice, such as crop variety selection, fertilization, irrigation scheduling, or weed control, or in formulating resource management policies, such as soil conservation, commodity price supports, or regulation.

Decisions in production agriculture require information concerning the most effective farming operations, as well as the most efficient allocation of resources. Socioeconomic and political changes beyond the control of the individual producer further complicate the decision-making process (*2*). Therefore, information required to make sound management decisions comes from many diverse sources.

In the context of agricultural management systems, we define specificity as the level of informational detail required for the most appropriate management decisions. The level of specificity in a given recommendation depends on the person using the information and changes with the user's changing values.

Knowing that our research data from a variety trial, a nitrogen response experiment, or a herbicide screening test will reach many audiences, we have to package the information in such a way that it will be interpreted as correctly as possible by a range of people with differing interests, needs, and levels of understanding. This is not an easy task. Our experience with the types of variation that occur within fields, among fields and locations, and over years makes us cautious in extrapolating results from one set of conditions to others.

What recommendations are appropriate to a wide range or a narrow range of conditions? Do some technologies have wider applications than others? How do production situations differ, and do these differences influence the application of a given technology? Answers to these questions emphasize the need for specificity and a holistic approach to research. Specificity can ensure sustainability through adoption of the most appropriate existing technologies.

Changing values and specificity

The ways in which each person looks at a crop depend upon his or her unique relationship with that crop and can be described along a spatial or geographic continuum. National policymakers are concerned about the performance of the entire crop in the country each year, for example, in terms of export earnings or food prices. Specificity of a given legislator's interest extends to how well the crop performed in his or her district. At the other end of the spectrum, the person most interested in the individual plant may be the research scientist who is examining gene segregation patterns or translocation of radioactive tracers in a physiology study. The farmer is most concerned about how to make decisions, based on the best available information, for his or her own farm. These decisions will be fine-tuned to individual fields on that farm and only rarely to specific sites within a given field.

Formulation, conduct, and evaluation of research intended to generate specific recommendations must be responsive to changing value criteria by which agricultural specificity is measured. There is an increasing concern about narrow measurement methods (bushels/acre or net profit/acre) that do not reflect the sustainability of a system. How do we measure production per unit of a renewable or nonrenewable resource, per unit of environmental impact? Our best minds would do well to explore these alternatives to ensure appropriate recommendations.

Within a specific user-group class—agricultural producers—increased specificity of information, coupled with the adoption of new evaluation criteria, can result in reduced inputs in agricultural production. Research into "prescription" or field-specific recommendations has yielded promising results. Weed scientists researching and implementing economic threshold criteria into weed management decision-making have found ways to reduce herbicide use in grain-crop production. Such an approach requires that individual fields be scouted and appropriate

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weed control recommendations implemented. If the weed infestation for a specific field is below the economic threshold—that is, the weed population at which cost of control equals anticipated loss attributable to weeds—no herbicide treatment is recommended (*3*). Such a management approach promises to reduce significantly the 340 million pounds of herbicides applied annually in the United States.

Farmer-targeted decision-making programs are under development at several land grant universities around the country (*9*). And in West Germany, where economic threshold criteria are used to regulate small grain weed control programs, significant reductions in herbicide use have been documented (*11*). Under development are more elaborate weed control decision-making tools that rely on field-specific weed seedbank and seedling data to arrive at control strategies (*5*). Results indicate that significant reduction in herbicide use will result if such field-specific information about pest populations is considered.

Nitrogen is one of the most costly and energy-intensive inputs in row-crop production. Nitrogen fertilizer recommendations, based upon regional differences in climate and soils, vary from state to state. Often the differences in nitrogen recommendations are as abrupt as the state boundaries.

In Nebraska, nitrogen recommendations are based upon years of statewide fertilizer calibration studies. These recommendations are summarized in algorithms that address the nitrogen requirements of individual crops, as well as the diversity in management practices that influence nitrogen supply, such as tillage, irrigation, or crop rotation. Incorporated in these algorithms are variables specific to the field in question and to the management history of the farm. Variables include the level of residual soil nitrate nitrogen and the yield goal of the individual producer. These variables add field specificity to the nitrogen recommendation and also demonstrate the essential role the producer plays in deciding the level of nitrogen to apply.

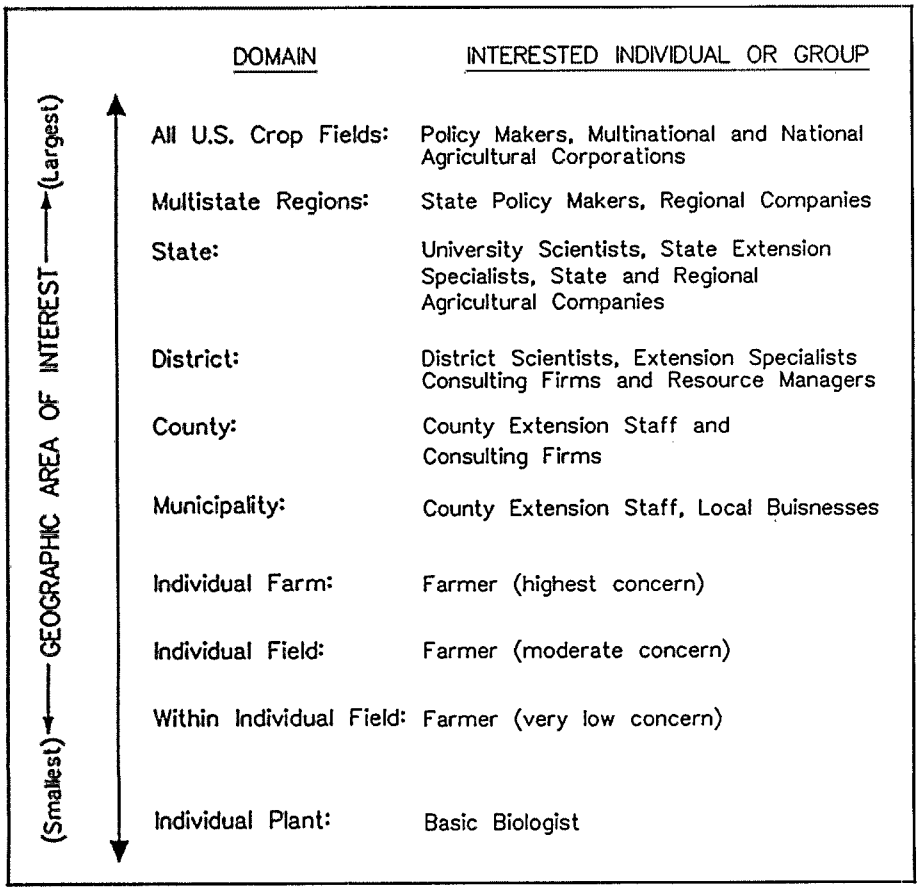
Extension efforts to promote residual nitrate testing and to educate farmers about the importance of realistic yield goals can result in substantial gains in farm profitability through reductions in unnecessary fertilizer nitrogen inputs. Concurrently, they can reduce the negative environmental impact of nitrogen on groundwater supplies.

Often, adapting specific technologies across broad regional boundaries is compelled by changes in public attitude, signifying a change in values. Fertilizer nitrogen management is now being regulated by law in the Central Platte Valley of Nebraska, where nitrate contamination of groundwater has reached a level unacceptable to the public (*8*). Residual soil nitrate as a basis for nitrogen recommendations has been in use for several decades in the more arid regions of the United States. Here, the potential for leaching of nitrogen is much lower than in regions with higher rainfall (*12*). With the energy crisis in the 1970s and, more recently, the public concern over groundwater contamination by nitrogen, residual soil nitrate testing is gaining interest in the more humid eastern United States. As a result, new and innovative techniques of using this technology are being explored (*10*).

In choosing an appropriate crop variety, the producer draws on a range of personal experiences and other sources of technical information. The producer's immediate concern is how well the chosen crop variety will perform on his or her farm in the current year. University agronomists in charge of uniform testing want to collect unbiased information from each district and from around the state, whereas university plant breeders are involved in development of germplasm adapted to the range of conditions found in their state. Commercial breeders in smaller companies can focus on the unique conditions in their region and select for specific adaptation to that area, and breeders in larger national companies want to provide varieties that have high yields across as wide an area as possible.

Recommendations as to which varieties to plant depend upon where data were collected, levels of management used, and who conducts and interprets the test results. Growers have to assimilate information from all of these public and private sources on specific concerns, such as yield, percent moisture at harvest, standability, yield in moisture-stressed environments, and stand establishment in reduced tillage. Both public and commercial agronomists are addressing these concerns, and they must be considered in local recommendations.

Geographic or spatial domains across which recommendations or decisions are made for specific production practices.



A systems approach to research

The examples mentioned emphasize ways in which field-specific recommendations can optimize a component of a farmer's production system. For the most part, these applied technologies have developed within discipline-oriented research programs. The existing structure for problem-solving in academic institutions is discipline-based and generally reductionist in approach.

As such, it becomes constrained by these disciplinary boundaries and the breadth of the individual researcher. Interactions of other undefined subsystems within the study area may remain untested because of the inexperience of the researcher. Conversely, potentially confounding variables may be eliminated to reduce the problem to simple, testable hypotheses.

Applied research conducted under this approach has resulted in enormous strides in our agricultural productivity, as witnessed by the food surplus in this country. Adaptation of technological advances from experiment station to farm, however, is often delayed because of the time required to interpret and integrate research results before using them in a wide range of dissimilar conditions on the farm (*14*).

The globalization of economies and the environmental and political impacts of our agricultural production systems on both rural and urban populations require that new technologies be conceived and researched in a holistic manner. This system perspective must be taken when solving agricultural problems because the producer has to integrate these technologies into an entire production system. Increases in productivity have not always translated into improved economy of the farm household. Optimizing one component is not satisfactory; rather, the entire production system must be studied.

This approach must examine the variety of factors that alter specific components of the production complex, including the impact of introduced technologies on national agricultural policy, and vice versa (*1, 7*). The concept of specificity must become a priority in our national agricultural research strategy if we are to remain competitive as a nation (*4*).

Conceptualizing, studying, and implementing research that is specific and yet holistic is a formidable challenge. Although continuing to bolster output by solely increasing inputs is largely considered unrealistic, new research approaches will be necessary for redirection. There are many institutional and interpersonal barriers to the interdisciplinary activities necessary for successful systems research (*6, 13, 15*). Examination of comprehensive management systems by conventional agricultural scientists, sociologists, and economists will require interdisciplinary teams capable of communicating in a common language and bridging disciplinary boundaries to create management models specific to the needs of the targeted client group.

The advantages of system modelling are many. Requiring formulation of subsystem models to incorporate interactions, system models naturally form the stimulus to bridge disciplinary research efforts. Validation and sensitivity analysis of models provide a guide to research and focus resources toward the research efforts that are most critical to the model's success and utility. Model building on an interdisciplinary base can provide the key to constructing comprehensive regional management models that lend themselves to planning, education, rapid technology transfer, and specificity.

Deep soil nitrate-nitrogen sampling is one example of an activity that results in specific information for farm management decisions.

Conclusions

Agricultural producers are flooded with production information from a multitude of sources. Much of this information is generic, with varying degrees of relevance to an individual's production system. Implementation of such generic information may not permit the optimization of crop production systems. As indicated in the examples cited herein, implementation of farm- and field-specific recommendations allows the producer to adjust his or her practices consistent with the best available technology, and it can, in turn, reduce occurrences of fertilizer and pesticide over-application. The technology does exist to attain sustainability and increase profitability.

Because the farmer is an integrator, recommendations must not be confined to single disciplines, but instead must consider the many facets and interactions in the production system. As researchers, we must remain cognizant that our research results are subject to interpretation by a variety of individual user groups. As such, these results are evaluated under different value strictures. The complexity of the agricultural ecosystem and the diversity of individual goals require integration of information on the part of the client but, more important, a system of information that is itself integrative. For agriculture to remain sustainable, decisions must be made that are beneficial for society as a whole, in terms of environment and food quality, as well as profitable for the client.

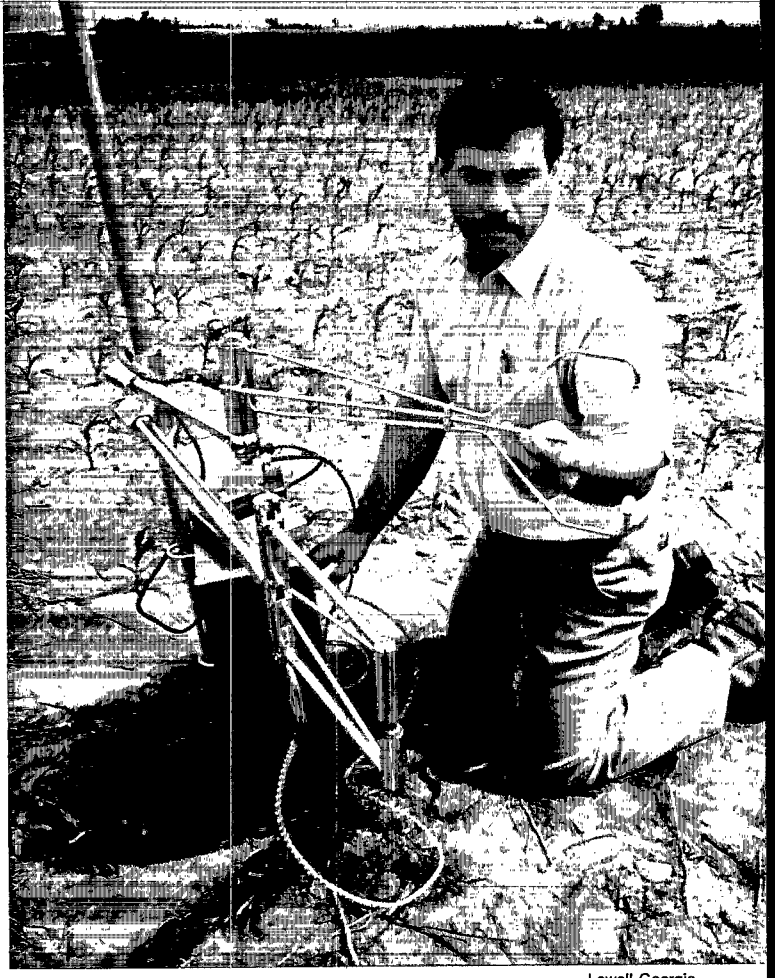
REFERENCES CITED

1. Ames, D. R. 1989. *Need for integrated livestock management.* In A. Weiss [ed.] *Climate and Agriculture: Systems Approaches to Decision Making.* Dept. Agr. Meteorology, Univ. Nebr., Lincoln. pp 14-19.
2. Bawden, R. J., R. D. Macadam, R. J. Packham, and I. Valentine. 1984. *System thinking and practices in the education of agriculturalists.* Agr. Systems 13: 205-225.
3. Coble, H. D. 1985. *The development and implementation of economic thresholds for soybeans.* In R. E. Frisbie and P. L. Adkisson [eds.] *Integrated Pest Management on Major Agricultural Systems.* Texas A&M Univ., College Station. pp. 295-307.
4. Holt, D. A. 1987. *A competitive R & D strategy for U.S. agriculture.* Science 237: 1,401-1,402.
5. King, R. P., D. W. Lybecker, E. E. Schweizer, and R. L. Zimdahl. 1986. *Bioeconomic modeling to simulate weed control strategies for continuous corn* (Zea mays). Weed Sci. 34: 972-979.
6. MacRae, R. J., S. B. Hill, J. Henning, and G. R. Mehuys. 1989. *Agricultural science and sustainable agriculture: A review of the existing scientific barriers to sustainable food production and potential solutions.* Biol. Agr. & Hort. 6: 173-219.
7. Marcotte, P., and L. E. Swanson. 1987. *The disarticulation of farming systems research with national agricultural systems: Bringing FSR back in.* Agr. Admin. Ext. 27: 75-91.
8. McCabe, D. 1987. *This NRD will impose fertilizer regulations.* Nebraska Farmer, (Oct.): 18.
9. Mortensen, D. A., and H. D. Coble. 1989. *Bioeconomic decision-making models for weed control.* Weed Tech. (In review).
10. National Fertilizer Development Center. 1989. *Soil nitrate testing workshop: Research and extension needs in humid regions of the United States.* Proc., Workshop, Nat. Fert. Develop. Center, Tenn. Valley Authority, Muscle Shoals, Ala. 7 pp.
11. Niemann, P. 1986. *Mehrjahrige anwedung des schadensschellen prinzeps bei der unkrautbekampfung auf einem landwirtschaftlichen betrieb.* Proc., Eur. Weed Res. Soc. Symp., Economic Weed Control. European Weed Res. Soc., London, Eng. pp. 385-392.
12. Olson, R. A. 1984. *Nitrogen use in dryland farming under semiarid conditions.* In R. D. Hauck [ed.] *Nitrogen in Crop Production.* Am. Soc. Agron., Madison, Wisc. pp. 335-348.
13. Rawlins, S. L. 1988. *Systems science and agricultural sustainability.* National Forum: The Phi Kappa Phi J. 68(3): 19-22.
14. Ruttan, V. W., G. W. Norton, and R. R. Schoeneck. 1980. *Soybean yield trends in Minnesota.* Minn. Agr. Economist (July) 621. pp. 4-7.
15. Weiss, A., and J. G. Robb. 1989. *Challenge for the future: Incorporating systems into the agricultural infrastructure.* J. Production Agr. 2: 287-289. □

Farmers and university researchers in four midwestern states offer their views on what direction research efforts should take in devising sustainable production systems

Research needs for sustainable agriculture

By James J. Vorst



Lowell Georgia

SUSTAINABLE agriculture is extremely difficult to define. Each person has their own perspective on its definition and may prefer such terms as reduced-input, regenerative, or alternative agriculture to describe our ideas. The difficulty arises from the fact that we are defining a value or mindset rather than a prescription or specified set of practices to follow. Therefore, on a higher level, people may be talking about the same concept, although their methods of approaching this concept are different. Sustainable agriculture means different things to different people.

Many farmers have definite ideas on what needs to be done to make agriculture more sustainable and how to make reduced-input farming methods more productive and profitable. However, because of the diversity inherent in agriculture and because farmers have no unified voice, their ideas on the direction agriculture should take and what is needed to get these ideas implemented often is not considered. On the other hand, researchers at land grant institutions conduct research encouraged by their academic disciplines. Research is often shaped by the monies they can attract and particularly by the guidelines inherent in private grants and state or federally funded projects. Direct input into research programs from farmers has been minimal or comes from farmers who have taken a more conventional approach in their operations.

Workshops or conferences in which farmers and university researchers and administrators openly discuss needs and directions of agriculture are excellent vehicles for fostering communication and reducing misconceptions. The university research system is responsive to the needs of agriculture, but it must be informed of these needs. While lack of funding may continue to be a problem in sustainable agricultural research, one method to increase funding is for farmers to let legislators know of their needs. Because the goal of all agriculturalists is to improve the food and fiber production system, discussion and debate on all facets of agriculture among everyone involved in the system is necessary if long-term, sustainable agriculture is to be achieved.

In an effort to provide a forum for communication between farmers, university administrators, and researchers, four workshops were conducted between November 1987 and August 1988 by the Midwest Technology Development Institute and the Rodale Institute in Illinois, Indiana, Michigan, and Ohio. With financial support from the Charles Stewart Mott Foundation, there were 238 participants in the four meetings. Attending were 127 farmers and 62 university personnel. The remaining participants consisted of government employees and agribusiness people.

As with so many issues, the question of whether the issues are real or perceived is widely debated. However, the issues of sustainable agriculture and the future of farming was reflected by the perceptions of farmers who participated in these workshops, and their actions on the land are based on those perceptions.

Understandably, these farmers are concerned about both the long-term and immediate future of agriculture. And they are just as concerned about making a profit and improving the quality of life for their families and the general public as are their counterparts who use high-input, chemically based systems. These farmers feel, however, that the type of information they need is either unavailable or so difficult to access that they cannot find the necessary help for solving everyday production problems. Perhaps part of the problem lies in the fact that agriculture is in an era of phenomenal and rapid change; communication between researchers, the Extension Service, and farmers representing a variety of production systems needs to be strengthened. Many of the farmers' concerns are being researched and published in pro-

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fessional journals, only to be read by other professionals instead of being disseminated in forms readily accessible to the farmer.

Successful systems

Sixteen farmers who are now using some type of reduced input or components of sustainable production systems explained their philosophy and the general characteristics of their operations during the workshops. While there were significant differences in the management styles of the operations, each of these farmers expressed the opinion that they needed to adapt their management styles to a more sustainable-oriented approach to production economics. Economic sustainability was the major concern.

A summary of the major components of their management systems included the following basic characteristics: Ridge tillage and use of cover crops were an integral part of most production systems. All were interested in reducing the use of pesticides and commercial fertilizers and were using legumes in crop rotations and/or green manure cover crops as a nutrient source. Maintaining soil tilth with emphasis on organic matter was important, and using green manure crops in combination with reduced tillage to help improve soil tilth and was an essential feature of their management systems. Another key component of concern was the necessity of diversification for maintaining a sustainable production system.

The concerns of farmers attending the conferences ranged from the need for specific answers to immediate problems to long-range, more philosophical questions. The questions and concerns expressed were categorized into five main areas: soil fertility, pest control, alternative enterprises, cover crops and alternative nitrogen sources, and new technologies.

Soil fertility and ecology

Plant nutrition. How much nitrogen is retained in the soil from various cover crops, and what impacts do cover crops have on the carbon/nitrogen ratio? How do we best manage crops for optimum nitrogen production and availability, and is it advantageous to add nitrogen when growing nitrogen-fixing crops in the system? How should fertilizer application methods, forms, rates, and timing for reduced-input systems be modified from current recommendations? Do salt-based fertilizers affect soil physical and chemical conditions, and can the use of alternative cropping systems increase the release and availability of soil-borne nutrients? Increased availability of soil nutrients could directly affect fertilizer recommendations by reducing input costs and thus potentially reducing yields over a longer time period. If so, just how much can fertilizer rates and yields be reduced before profit is diminished?

Many new biological products are being marketed, but finding reliable results on these products is difficult. What is the validity of using these products in reduced-input systems? Can these products be tested according to manufacturer's recommendations and be validly compared with other factors affecting crop growth and nutrition?

Soil testing. Farmers rely heavily on soil testing to determine plant nutrient needs, but what is the accuracy of these test results, especially under reduced-input systems? Is there an optimum time or method of soil sampling under reduced-input systems, and how can plant analysis and tissue-testing procedures be refined to be more useful to farmers using reduced-input systems?

Tillage, manure, and sludge application. While we know that type, timing, and amount of tillage affect soils and crop production differently, the impact of both conventional and reduced tillage systems on soil tilth, porosity, and water-holding capacity under a wide range of conditions is not understood completely. How does the incorporation of cover crops affect these factors and the level of soil organic matter? What are the most effective tillage systems to use for optimum weed control in different crops, and when should this tillage be done? When is the best time to apply manure in various cropping systems to obtain maximum benefit? How should manure best be handled, and to which crops should it be applied to obtain maximum benefits? How should rates of manure application be determined for various types of manure and for different crops? How can municipal sludge be most effectively incorporated into a reduced-input system? How do all of these factors affect the microbial and invertebrate populations of the soil, both in conventional and reduced-input systems?

Pest control

Making the transition. Many farmers who would like to make the transition to reduced-input systems are deterred by pest problems. What are the greatest pest problems during transition, and how are these pests best controlled during transition? What is the best approach to the transition from high-input to low-input farming? While the economic threshold value of some pests is known, data for many other pests in reduced-input systems is lacking. What are the pest population shifts that occur in transition, and what causes certain pests to build up in some locations, whereas in other seemingly identical situations these pests are not a problem? In addition to researching the effects of pesticides on the pest, much more attention needs to be directed to the long-term effects of pesticides on the environment, personal safety, and food and feed quality. If the level of chemicals used in agriculture decreases, who will pay for the research presently being supported by the agrichemical industry?

Weed control. Weeds remain the primary pest problem and may be more serious now than they were 30 years ago. With the large arsenal of herbicides available, why do we still have a serious weed problem? Is this because of changes in cultural practices or because of pesticide-induced changes in the soil environment or weed species? A better understanding of the ecology of weeds, herbicide carryover in different and specific environments, and the effect of rescue treatments is needed. How should cultural practices be modified to best manage weeds, and how do specific weed control practices fit into a reduced-input system?

Alternative enterprises

An industry changing. The rapid pace of social change has created needs that are different from those of a decade ago. These changes also create a need for different types of agricultural products. Just as today's society makes extensive use of products from soybeans, a new crop 50 years ago, researchers need to be aware of the shifts in societal demands and how agriculture can safely and efficiently produce the raw materials for new products. The adaptation of biotechnology should be expanded, not only to increase production of plant and animal enterprises, but also to enhance the quality of agricultural products. Such questions as the purported nutritional superiority of organically produced products and background levels of toxic substances in all food products need to be answered. Besides the need for production information, additional market research and development is needed. How does one develop or gain access to a market for low-volume, high-value crops, and what are the trade-offs for these types of operations when compared with production of conventionally grown crops and livestock?

Crops. New or alternative crops are not being grown in many locations for a variety of reasons. Ecologically, these crops tend to be site-specific, and many may be suited to land not well adapted to row-crop production. A broadened ecological data base for specific crops adapted to specific niches, especially marginal land, is needed. Where

does one get information on production, adaptation, and management of alternative crops? What management strategies are most successful for low-acreage, high-value crops, and how is this information obtained? Are there additional alternative uses for traditional crops that would increase demand and thus increase both price and market?

Livestock. Additional research on effective production systems for smaller scale, low-input livestock systems is needed. How can livestock be produced using fewer pharmaceuticals? For swine, what are the source and best methods of preventing pseudorabies? Are there safe and effective biological methods of fly control? How can an effective certification system of chemical-free, low-fat beef and pork be developed? What are the best management methods for intensive grazing systems? How can feed grains with higher protein content be developed?

Cover crops, nitrogen sources

There are many questions about cover crop usage. Reduced-input systems frequently involve the use of cover crops both to conserve soil and as a source of nutrients, but are there additional benefits that have not been researched? How do cover crops fit into reduced-input systems? What is the net economic return from using cover crops in reduced-input cropping systems, and when is their use economically advantageous? Which cover crops are best for specific applications, and is it feasible for any of the hundreds of native species to be used as cover crops? Are there unknown allelopathic effects of cover crops that could be used advantageously in reduced-input systems to replace herbicides? Are there allelopathic effects on crops, and if so, how can they be avoided? Should an additional crop breeding objective be to improve characteristics of cover crops that would enhance the productivity and profits of reduced-input systems? How does one best control or kill a cover crop in a reduced-input system? Soil moisture depletion due to cover crops can be a problem, but this problem varies with such factors as soil type, rainfall, and succeeding crops. Cover crop modelling genetic selection efforts that take these variables into account need to be expanded. Cooperative efforts in cover crop modelling, as well as other areas, across the Midwest would appear quite beneficial.

New technologies

The agricultural research system has an almost unlimited potential for technological and scientific development. However, what is appropriate technology, and which avenues of science should be followed to secure the future of a sustainable agriculture? The environmental and social aspects of technological advancements need much closer scrutiny in the future. How do we best obtain this type of information? How influential should consumer preferences be in relation to potential environmental damage inflicted by adaptation of a new technology? Does present research and development tend to favor one segment of farmers at the expense of others, and if so, is this necessary, or even harmful, to our rural communities? Are reduced-input strategies receiving as much attention from research scientists, extension, and teaching personnel as conventional strategies? Is there a policy that determines research direction and assures input from both conventional and reduced-input farmers?

Agricultural research

A summary of responses provided by administrators and researchers from the land grant universities in each of the four states provides a perspective on the agricultural research picture. The issues addressed centered around the mission of agricultural experiment stations, funding priorities, and present and future directives of agricultural research. The following general overview of experiment station research constraints and directions provided a basis for increased communication between the farmers and university personnel.

When compared to industry-conducted research, the goals of university research tend to be less product-oriented and more management-oriented. Monetary and environmental considerations are creating increased demand for research in sustainable agriculture, and each of the universities represented is already conducting research that directly relates to sustainable agriculture. Some major factors affecting the type of research conducted include funding priorities, the expertise and interests of the research staff, and research priorities on the national level.

The three major funding sources are state and federal appropriations and grants received from private sources. While actual percentage breakdowns vary from state to state, federal and state appropriations tend to be the major source of research funding. It is difficult to quickly change research directions and priorities because most research resources (experimental plots, laboratories, and scientists) are supported by funding from public or private sources and are committed to research with specific objectives in mind.

While most research on sustainable agriculture presently is being funded by public sources, there are examples of privately funded research being conducted that relate directly to sustainable agriculture. Two notable examples include work being done on genetically engineered pest resistance to reduce the need for pesticides and conservation tillage research. In addition, centers for sustainable agricultural research are in place at some universities and in the planning stage at several others.

Viewpoints expressed by university researchers on farming systems and environment-oriented research included the importance of a systems approach to research and knowledge of the interactions of production components on the environment. Not all agricultural chemicals have the same ecological impacts, and not all environmental contamination is due to agriculture. Environmental contaminants include pesticides from both on- and off-farm use, nitrates in surface and groundwater, sediment, and bacteria. There are trade-offs that must be considered between the beneficial and harmful effects of using any production input. While the elimination of chemicals from some farming systems is possible, chemicals will continue to be used in agriculture, and research efforts in the university setting will continue to focus on management practices that provide the greatest beneficial trade-off for sustaining a healthy environment and enough profits to make farming economically sustainable.

For a farming system to be sustainable it must show a profit. Many factors, including costs of inputs and prices received, determine the economic feasibility of sustainable agriculture. Possible options for reducing input costs are the increased use of mechanical weed control; alternative methods of maintaining nitrogen, phosphorus, and potassium levels in the soil; and the electronic monitoring of planting, spraying, and other agricultural processes. Some of these new ideas are relatively easy to undertake, such as tuning up fertilizer programs, while others are so complicated that some farmers will never acquire the information and skill to successfully adapt them. In addition, location plays a role. Some ideas are more applicable in some areas than others, and some systems, because of the commodities produced, need to be close to their markets. In addition, the social, community, and family effects of changes in agriculture must be considered. Some social scientists are capable of researching these effects, thereby providing the public with clearer insights when deciding on the policies to adopt and the levels of risk that are acceptable with any food production system. □

Soil Conservation Service/Tim McCabe

LISA
Some early results

By J. Patrick Madden
and Paul F. O'Connell

THE U.S. Department of Agriculture's research and education grants program, known as Low-Input/Sustainable Agriculture (LISA), responds to an emerging interest by many farmers for a more cost-effective and environmentally benign agriculture. There is growing public concern about groundwater contamination, pesticide residue in foods, high cost of modern-day agriculture, soil health, and lack of crop diversity for wildlife habitat. LISA research and education projects are designed to help farmers substitute management, scientific information, and on-farm resources for some of the purchased inputs they currently depend upon for their farming enterprises.

The LISA program also has responded to a congressional mandate to involve a broader spectrum of the agricultural community in administering the program and carrying out the projects. Innovative methods are being used to enable scientists, educators, and farmers to work as teams in selecting projects to be funded, setting research goals, designing and implementing the projects, and devising strategies to ensure that the findings are made available to producers and other audiences.

The LISA program is administered through host institutions in four regions: the University of Vermont for the northeastern region, University of Nebraska for the north central region, University of Georgia for the southern region, and University of California for the western region. LISA project proposals are reviewed in each region by committees that include farmers, state experiment station researchers, educators in the Cooperative Extension Service, Soil Conservation Service (SCS) personnel, Agricultural Research Service (ARS) scientists, and others.

Scores of farmers who are successfully

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using low-input, sustainable farming methods of pest control and soil fertility management have become involved actively as members of project teams in preparing LISA project proposals. On-farm experiments are being designed and carried out by these project teams, using scientific methods for setting up treatment plots and measuring results, such as crop yields, soil conditions, and the populations of pests and their natural enemies. These on-farm studies are essential to the success of the program in that they bring together the findings obtained from laboratory and experiment station research. Together these studies are beginning to provide the reliable, scientific information producers must have to design a profitable strategy for reducing a farm's dependence on certain kinds of off-farm inputs.

Although the LISA program has received a total of only $12.8 million for its first three years of operation, an amazingly large and diverse array of scientists, educators, farmers, and other interested persons in the public and private sectors have already become involved. Despite the short time it has been in existence, meaningful results are arising.

Genesis of LISA

The LISA program was created in response to the 1985 Food Security Act, Subtitle C, Agriculture Productivity Research. In 1986, USDA policymakers began discussions with farmers and other proponents of farming systems that relied less on synthetic chemicals and other off-farm purchased inputs. They visited the Rodale Research Center near Emmaus, Pennsylvania, and toured Dick and Sharon Thompson's farm near Boone, Iowa. They attended a conference of interested scientists, farmers, foundations, and public agencies in Racine, Wisconsin, and held informal discussions with many experts and practitioners of various low-input, alternative farming methods.

Those policymakers found farmers were looking for ways to increase their net return while reducing risks and achieving greater compatibility between environmental and production goals. They also found that a handful of dedicated university and private-sector researchers were studying scientific components essential to the success of these low-input farming systems, despite extremely limited funding. It became abundantly clear that federal funding was urgently needed to support private and public research and educational efforts to enhance the productivity and profitability of low-input farming methods and systems.

Throughout 1987, congressional hearings were held. The program received its initial $3.9 million appropriation in December 1987. In January 1988, the secretary of agriculture issued a memorandum establishing departmental policy regarding alternative (now termed low-input/sustainable) farming systems: "The Department encourages research and education programs and activities that provide farmers with a wide choice of cost effective farming systems including systems that minimize or optimize the use of purchased inputs and that minimize environmental hazards. The Department also encourages efforts to expand the use of such systems."

The LISA program has been organized and directed by the Cooperative State Research Service (CSRS), with the full cooperation of the Extension Service and other USDA agencies, especially SCS, ARS, and National Agricultural Library. The program has unfolded rapidly. Whereas it normally takes at least 12 to 18 months to establish a new federal program of this kind, in just 6 months a set of administrative guidelines were developed, technical committees and administrative councils were formed in each of the four regions, hundreds of project proposals were submitted and reviewed, and the first round of projects were approved for funding. These projects encompass a wide range of subject matter germane to low-input, sustainable agriculture.

The LISA program responded to the congressional intent regarding involvement of a wide range of public and private organizations. Specifically, the program has the meaningful involvement of farmers, interdisciplinary cooperation in research activities, and functional integration of research and extension, and a significant share of funds has been allocated to 13 private research and educational organizations.

Of 371 projects submitted to the four regional host institutions, the review committees determined that 130 were acceptable in terms of their relevance to LISA goals, appropriate methods, and feasible plans for making the findings readily usable to farmers. Of the 130 projects, the best 53 were selected for funding. Several similar proposals were combined to form a total of 49 projects. If more funding had been available, an additional 77 projects would have been funded. The total cost of fully funding the 130 acceptable proposals in 1988 would have been $16.6 million, roughly five times the amount available.

In fiscal years 1989 and 1990, Congress appropriated $4.45 million for LISA, a 14 percent increase over 1988. The current level of funding is an average of $1.99 per farm; it amounts to less than one-thousandth of the annual sales of pesticides in the United States. During the first two years, a total of 802 proposals or pre-proposals were submitted for review; 78 were funded. Three of the four regional selection committees (northeastern, north central, and southern) will complete their 1990 project selection and funding allocations by June. In view of the limited funding, the western region committee has opted not to call for new proposals in 1990, but to continue support for existing projects.

Most of the LISA projects are long-term studies requiring several years development and replication before scientifically meaningful results can be obtained. A few of the projects have added to on-going studies, by providing resources for additional treatments, more measurements of soil and biological attributes, economic evaluation, and more effective means of getting the findings out to farmers. Other projects are of a short-term nature, such as preparation of video tapes demonstrating such methods as ridge tillage and composting, preparation of computer software, or other approaches for presenting known findings and forthcoming results in ways that will be readily usable to farmers and other clients.

Field crop production. The farm press has begun featuring stories of farmers who are using low-input methods successfully. For example, in a *Farm Journal* article about Don Elston of Ohio and Joe Federer of Indiana, Federer said his move to low-input methods was motivated by his concern about possible effects of chemicals on human health. Using such practices as crop rotations, cover crops, cultivation, and rotary hoeing, Elston and Federer reduced their fertilizer costs by $17 and $34 per acre, respectively.

Farmer awareness of low-input opportunities is also increased by hands-on experience. Thousands of farmers each year attend field days on farms with demonstration plots comparing low-input and conventional methods. For example, during 1988, some 900 visitors to Dick and Sharon Thompson's farm saw side-by-side comparisons of conventional and low-input farming practices. Such methods as ridge tillage, legume-based rotations, and an integrated crop-livestock system produced the highest oat yield in Story County, Iowa—142 bushels per acre. Their corn and soybean yields were 27 and 17 bushels above county averages, respectively. The methods used by the Thompsons result in substantial reductions in cost and soil erosion as compared with conventional farming practices in their area.

Several projects funded by LISA are providing a scientific basis for understanding the productivity of low-input systems. For example, experimental plots comparing conventional and low-input crop rotations were

started by Larry King in 1986 at North Carolina State University. With LISA funding, his study was expanded to include several additional disciplines. The additional tests and treatments included investigation of weed management strategies, such as allelopathy; natural weed control; soil moisture relations; soil insects, nematodes, and microbiology; cycling of nitrogen, carbon, and phosphorus; economics; and extension. The first three years of the project were characterized as summer droughts. Johnsongrass infestation was extraordinarily heavy. Because of the drought, all crop yields were below normal. The lowest corn yields were found in continuous corn plots. Somewhat higher yields were found in the low-input plots, but the highest corn yields were obtained using the conventional (pesticide-based) crop rotations.

Costs and net returns from corn, soybeans, grain sorghum, and wheat were calculated for each treatment in 1986 and 1987. Net returns were higher in virtually all of the low-input plots than in the conventional plots. Because of the drought, the net returns for most of the enterprises were negative. Conventional management in this experiment is no-till production, with heavy reliance on herbicides. Low-input methods rely primarily on crop rotations and mechanical cultivation for weed control and on legumes for nitrogen. Production cost on the conventional corn plots in 1987 was $218 per acre; the low-input methods required $128. Because yields were so low, the conventional corn plots incurred a net loss of $171 per acre, compared with a net loss of $95 in the low-input plots. The most dramatic contrast was in soybeans during 1986. Net return from the conventional soybean plots averaged a loss of $26, compared with a profit of $47 per acre under low-input management. As additional years of data are accumulated, this study will provide increasingly definitive conclusions about the profits and risks of low-input farming methods in this part of North Carolina.

The Spray Brothers farm in Ohio is 720 acres, with a beef herd of 40 to 50 head. They have used no herbicides, lime, or fertilizers on their farm since 1971. Nonetheless, their crop yields are above county averages: corn, 32 percent above average; soybeans, 40 percent; wheat, 5 percent; oats, 22 percent. Clover hay yield is 6 tons per acre (no county average for comparison). The Sprays receive premium "organic" prices for most of their crops and some of their beef.

Another illustration is the Sabot Hill farm near Richmond, Virginia, operated by Sandy Fisher. The farm is 3,480 acres, half of which is forest. Fisher has about 500 head of beef cattle. Over the years, johnsongrass has been a major problem in production of corn and soybeans, his primary cash crops. Johnsongrass has exhibited resistance to herbicides, requiring higher costs for chemical weed control, but with decreasing effectiveness. Fisher shifted from chemical control to a cultural practice of overseeding his johnsongrass-infested fields with legumes. After harvesting hay crops from these fields for two or three years, he found that the johnsongrass becomes depleted, so he can resume planting row crops without using herbicides. As a result of this change in practices, his herbicide cost have fallen $20,000 per year, and he is now achieving better weed control.

A team of scientists at South Dakota State University started a crop rotation study in 1985 comparing conventional and low-input crop rotations. The conventional options being tested in this on-going study include a choice of ridge tillage or minimum tillage, with farming systems typical of two locations, the Watertown and Madison areas (*2*). When this study became a LISA project in 1988, the scope of investigations was expanded to include whole-farm studies on several cooperating farms, biological control of pests, nutrient cycling, and soil properties. Economists on the project team have adapted the experimental findings from the first three years to develop preliminary estimates of the net returns that would be earned by a typical 640-acre family farm with 540 tillable acres.

During the drought of 1988, the only systems tested in this South Dakota study that were estimated to earn a profit were the low-input systems. The low-input farming system for the Watertown area was estimated to earn a profit of about $4,900, using a crop rotation of oats, alfalfa, soybeans, and spring wheat. The simulated farms in this area, using a conventional rotation (corn, soybeans, and spring wheat) with chemical pesticides and conventional tillage, incurred a net loss of about $25,000—a difference of about $30,000 compared to the low-input system. The differences in earnings were much smaller for the Madison area. The low-input system for this area was estimated to break even, while the minimum tillage and conventional systems lost about $15,000.

Another study in South Dakota has devised an improved method for corn rootworm control, which constitutes one of the largest single insecticide markets in U.S. agriculture. During 1988, insecticide was applied to about 35 percent of the corn acreage in the 10 Corn Belt states, representing a total of 18.7 million acres. Farmers typically apply a granular insecticide, usually an organophosphate, at planting time. This granular material is vulnerable to movement by wind and water erosion, possibly posing a significant risk to groundwater and surface water. Scientists estimate this material kills only about 50 percent of the corn rootworm larvae, which is the stage of the pest that does the major damage to the roots of the corn plants. In mid-summer, an aerial spray of insecticide often is applied to control the surviving adult corn rootworms. While this spray is highly effective in killing corn rootworm adults, it also kills beneficial species, including natural enemies of various pests, thus causing secondary infestations.

In an effort to reduce the environmental impact and protect water quality risk associated with control of corn rootworm, ARS scientists in South Dakota have devised a bait that is a starch crystal containing about two teaspoons per acre of an insecticide, carbaryl (*6*). While this is only about 2 percent of the normal dosage, tests in the laboratory and in field cages under controlled conditions have found that the bait kills up to 94 percent of the adult corn rootworms, with no harm to nontarget species.

Lowell Georgia

Researchers examine a soil core from a conservation-tilled field to study how such practices affect soil tilth.

The bait contains two kinds of semiochemicals (behavioral modification chemicals). The first is an attractant that lures the male and female adult corn rootworms to find the starch granules scattered about the field. The second semiochemical is a feeding stimulant made from a bitter herb that is delicious to the corn root worm but repugnant to most nontarget species, such as birds. Plans are now being developed for a full-scale field test of the bait under actual farming conditions in several states.

Fruit production. As part of a multistate LISA project, scientists at Cornell University have successfully tested a nonpesticide method of reducing the population of grape berry moth, a major pest of grapes, by using pheromone devices to disrupt the mating behavior of adult males (*1*). Test plots of grapes have been established on several farms, including seven vineyards in 1988. "Twisties" that emit a pheromone are attached to selected vines. In comparison plots, the conventional practice of spraying insecticide two to four times per season was followed by the farmers. The pheromone treatment suppressed grape berry moth populations below the economic threshold of damage in virtually all plots over a four-year period, providing results not significantly different from the chemically treated plots. An added advantage of the pheromone treatment in comparison with the use of chemical pesticides is that it does not decimate populations of beneficial species, including natural enemies of pests. While these results are encouraging, scientists caution that more years of testing are required under a wide range of conditions before the efficacy of this method can be established.

Steven Pavich and Sons, with 2,200 acres of vineyard in California and Arizona, produce more than 30 million pounds of fresh table grapes a year, about 2.4 percent of the nation's total production. While 85 percent of their acreage is certified for organic production under California law, only about 40 percent of their grapes are sold under the Pavich brand name, meaning they are "organically grown" and "Nutriclean"-certified as pesticide free. The Pavichs apply about 8,000 tons of composted steer manure as the main source of soil nutrients. They have not sprayed any synthetic chemical pesticide in any of their vineyards since 1986. That year, a newly purchased vineyard in transition was sprayed once. Their major strategy for pest control is to maintain a ground cover of native weeds, grasses, and legumes between the rows to provide a habitat and food source for natural enemies of the pests.

Experiments being conducted at a University of Georgia experimental farm are comparing three methods of controlling fungus disease in peaches: organic, low-input, and conventional (*4*). The organic treatment, designed in consultation with Georgia Organic Growers Association, relies on sulfur dust to control fungus diseases and various natural materials, such as rotenone, ryania, and pyrethrum, to control insects. The conventional treatment consisted of spraying the entire orchard with synthetic chemical fungicide and insecticide; in the low-input option, alternate rows were sprayed rather than every row. Brown rot was controlled equally well with all three treatments. Control of two other pests, catfacing insects and curculio, was slightly less efficacious in the organic treatment, with differences ranging from two to five percent. The low-input (alternate row) method of spraying provided slightly better efficacy than conventional spraying to control a heavy infestation of plum curculio and a moderate population of plant bugs.

In another portion of this study, apple orchard scouting techniques proved ineffective in reducing sprays for two fungus diseases, sooty blotch, and fly speck. Spraying every two weeks (five applications) between May 15 and August 1 was ineffective in preventing these diseases. However, a post-harvest method of removing fungus from the fruit was effective: 15 minutes soaking in bleach (0.0525 percent sodium hypochlorite). These results suggest that fungicide use could be replaced by post-harvest application of a rather harmless substance to the fruit.

In experimental plots of strawberries near Lubbock, Texas, scientists are comparing conventional chemical fumigation of the soil with solarization to control nematode pest populations and weeds (*9*). Solarization is a process of covering the soil with two layers of polyethylene separated by a dead air space; this allows the sun to heat the soil to kill pests. Nematode populations were reduced 85 to 90 percent by solarization, compared to 90 to 95 percent control using chemical fumigation. Similar experiments in eastern Texas found no significant differences in nematode populations between solarization and fumigation treatments. Yellow nutsedge was suppressed most effectively by solarization.

Conclusions

What many farmers are finding is that when they adopt low-input methods, including careful management, gross returns decrease slightly, but net returns increase. For example, in an 11-year study of Illinois farmers (1976 to 1986), Robert Hornbaker found that farmers using the highest amounts of purchased inputs per acre harvested more bushels but earned less profit per acre compared with farmers using less input per acre. The study examined data from a sample of 161 farms drawn from the University of Illinois farm records system. The farms were ranked according to their per-acre expenditures for commercial fertilizers and agricultural chemicals. The top one-fourth of the farms in this ranking were considered the "high-input" group. The quartile of farms having the lowest expenditure per acre were the "low-input" group. In 8 of the 11 years of his study, Hornbaker found the high-input group's net income per acre was significantly less than that of the rest of the farms (personal communication). On average during the 11-year period, the high-input group had $37 per acre more gross income than the low-input group, a difference of 11 percent. But their net income per acre was $29 less, a difference of 17.6 percent.

Many other examples could be cited, but these cases illustrate the kinds of technologies being developed and tested under the LISA program. Certainly, not all low-input methods being tested are proving to be effective or profitable. But, in general, the outlook is optimistic. Particularly encouraging is the fact that a large and growing number of scientists and educators at universities and in extension offices, as well as farmers and others in the private sector, are forming project teams to design and carry out studies to develop and test low-input farming methods.

REFERENCES CITED

1. Dennehy, T. J., L. C. Clark, C. J. Hoffman, and J. P. Nyrop. 1989. *Pheromone ties provide excellent control of grape berry moth.* Press release. Cornell Univ., Ithaca, N.Y.
2. Dobbs, Thomas L., and Clarence Mends. 1989. *Economic results of SDSU alternative farming systems trials: 1988 compared to 1987.* So. Dak. State Univ. Econ. Commentator 270: 3.
3. Economic Research Service. 1989. *Agricultural resources situation and outlook report.* AR-13. U.S. Dept. Agr., Washington, D.C.
4. Hendrix, F. F., Dan Horton, Norman McGlohon, and Douglas Pfeiffer. 1989. *Report on low-input agriculture grant on peaches and apples.* Dept. Entomol. and Plant Path., Univ. Ga., Athens.
5. King, Larry D. 1989. *Low-input cropping system experiment.* Dept. Soils, N. Car. State Univ., Raleigh. 13 pp.
6. Lance, D. R., and G. R. Sutter. *Field and laboratory evaluations of semiochemical-based baits for managing western corn rootworm beetles.* J. Econ. Entomol. (in review).
7. Madden, Patrick, 1988. *LISA 89 guidelines.* Coop. State Res. Serv., U.S. Dept. Agr., Washington, D.C. 13 pp.
8. Madden, Patrick, James A. DeShazer, Frederick R. Magdoff, Neil Pelsue, Charles W. Laughlin, and David E. Schlegel. 1989. *LISA-88-89—Low-Input Sustainable Agriculture Research and Education Projects funded in 1988 and 1989.* Coop. State Res. Serv., U.S. Dept., Agr., Washington, D.C. 155 pp.
9. Patten, Kim. 1989. *Solarization and living mulch to optimize lowinput production systems for small fruits.* Ann. Rpt., S. Reg. Low-Input Agr., Texas Agr. Exp. Sta., College Station. 3 pp.
10. Smith, Darrell. 1988. *Taking the low road.* Farm Journal (Dec.): 15-17. □

Soil Conservation Service/Gene Alexander

Practical applications of low-input agriculture in the Midwest

By Charles A. Francis

TODAY'S realities for Midwest farmers include gradual increases in costs of production inputs and continuing declines, in real terms, of prices received for principal feed grain products. Nationwide, farmers have reacted to current economic pressures and environmental concerns by reducing purchased inputs over the past five years by about 15 percent—more than $20 billion. Biological realities include lower potential productivity as a result of topsoil loss, higher costs for pumping irrigation water because of lower groundwater levels, and increased needs for fertilizers and pesticides.

More and more people are becoming aware of some of the unintended consequences of diligent application of conventional products and use of recommended techniques. The environmental realities include high groundwater nitrate levels in some areas, presence of pesticides and residues in some wells, and off-target effects of herbicides and insecticides. Surface runoff of suspended clays, soluble nitrate, and some pesticides has reached streams and lakes. These problems have been reported and discussed in recent symposia and publications (*5, 7, 9, 21*).

Global environmental implications of current practices have been discussed in the annual publication *State of the World 1989* (*4*). Most analyses of the current situation call for a search for alternatives.

Low-input, sustainable agriculture

Great confusion surrounds the real meaning of sustainable agriculture. For some, the term "low-input" conveys the impression that proponents advocate a return to labor-intensive, nonchemical methods of the past. Considerable baggage is attached to some terms because of their association with certain individuals or groups. This "name game" is discussed in depth by Lockeretz (*18*).

Although the general perception is that industry does not seriously consider reducing purchases of production inputs, today's advertising copy reflects an obvious awareness of the importance of this strategy to farmers. Progressive companies are carefully charting a course toward new-generation products and methods that will help to offset some of the negative environmental consequences of chemical use.

The concept of external resources (purchased, fossil-fuel derived, nonrenewable, perceived as potentially polluting) versus internal resources (on-farm, renewable, perceived as environmentally benign) has been developed as a way to evaluate where and how production inputs are derived (*13*). Proponents of sustainable agriculture suggest that substituting an internal resource, for example, biologically fixed nitrogen, for all or part of an external resource, for example, anhydrous ammonia or urea, can help shift the balance toward greater reliance on internal inputs and make systems both more profitable and more sustainable. Midwest farmers are making some of these changes, although they often do not use the same terms to describe their modifications in production practices.

Is this a return to the past? In fact, we can never go backward! Sustainable agriculture is as old as farming itself, yet as young as biotechnology or genetic engineering. This past year has seen many discussions, workshops, formal conferences, and new definitions. The debate continues (*18*). What is new is the broad array of players on the field. We have seen symposia cosponsored by the fertilizer industry, Rodale Institute, Farm Bureau, and Institute for Alternative Agri-

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culture. This is a healthy debate, and better awareness and understanding are certain results.

A definition of sustainable agriculture still has no consensus, although no one would advocate a "nonsustainable agriculture." In a recent symposium, Edwards (*8*) said that "sustainable agriculture involves integrated systems of agricultural production less dependent on high inputs of energy and synthetic chemicals and more management-intensive than conventional monocultural systems. These systems maintain, or only slightly decrease, productivity, maintain or increase net income for the farmer, are ecologically desirable and protect the environment."

At a special workshop of the American Society of Agronomy (2), this definition was advanced: "A sustainable agriculture is one that, over the long term, enhances environmental quality and the resource base on which agriculture depends; provides for basic human food and fiber needs; is economically viable; and enhances the quality of life for farmers and society as a whole."

In contrast to the definitions that include environmental and resource dimensions, others have proposed an economic approach to sustainability. Hoeft and Nafziger (*16*) proposed that sustainable agriculture is best defined or achieved by striving for maximum economic yield. This is the yield that gives the highest net return for each set of soil and climate conditions and, thus, the lowest unit cost of production. The Potash and Phosphate Institute (*19*) described the low-input, sustainable agriculture activity funded by USDA as a program designed to "reduce inputs and to convert conventional farmers to organic farmers." As an alternative, the institute proposed use of optimum levels of inputs that define the best management practices for each location.

Francis and Youngberg (*12*) discuss these contrasting opinions and present a consensus of those definitions that addresses both environmental and economic concerns: "Sustainable agriculture is a philosophy based on human goals and on understanding the long-term impact of our activities on the environment and on other species. Use of this philosophy guides our application of prior experience and the latest scientific advances to create integrated, resource-conserving, equitable farming systems. These systems reduce environmental degradation, maintain agricultural productivity, promote economic viability in both the short and long term, and maintain stable rural communities and quality of life."

Harwood (*15*) summarizes this philosophy in more concise form: "An agriculture that can evolve indefinitely toward greater human utility, greater efficiency of resource use and a balance with the environment that is favorable to humans and to most other species." Midwest farmers—though confused about the debate—are becoming aware of its importance and the need to consider seriously the stewardship of resources and long-term impacts of our industry.

Practicalities in the Midwest

To implement a philosophy without some specific guidelines about what practices are considered sustainable is difficult. It depends upon how we define sustainability, what time frame is considered, and what assumptions are made about long-term costs and availability of fossil fuel inputs. In a practical definition, agronomy Extension specialists (*1*) at the University of Nebraska have described sustainable agriculture in terms of these production decisions: "A management strategy that helps the producer to choose hybrids and varieties, a soil fertility package, a pest management approach, a tillage system, and a crop rotation 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."

In fact, farmers in the Midwest are already implementing a number of practices or strategies that can help sustain both productivity and profits while reducing the adverse effects of agriculture on the environment.

Crop choice, hybrid or variety choice. Plant breeders have made important gains over several decades in genetic resistance to pests, tolerance to stress conditions, and broader hybrid and variety adaptation (*10*). Some specific strategies that companies recommend and farmers are using include the following:

- ► Planting crop species that tolerate stress conditions or have high yield stability, for example, substitution of grain sorghum for corn.
- ► Choosing new hybrids or varieties with genetic resistance to predominant insect or disease problems.
- ► Testing and adopting varieties that show tolerance or avoidance of adverse climatic stress, for example, drought and low or high temperatures.
- ► Cutting back on crop maturity to minimize risk of loss at harvest and to reduce or eliminate costs of drying the crop.
- ► Planting a range of maturities of corn hybrids to avoid poor pollination in all fields and to spread the harvest activities.
- ► Using more diverse genetic materials to broaden adaptation to variable years and to increase production stability.

Management of soil fertility. Contrary to thinking only about what fertilizer package to apply next season, wise managers are now carefully setting yield goals and taking into account all fertility sources in the crop environment. Many of these alternatives are discussed in symposia proceedings (*3, 20*). Specific methods include the following:

- ► Setting realistic crop yield goals, based on measured yields over the past five years in each field.
- ► Taking deep soil samples for nitrate and other nutrients to see what is available through the entire root zone.
- ► Calculating nitrogen credits for legumes in the rotation, for nitrate in irrigation water, and available through mineralization from soil organic matter.
- ► Cautiously and conservatively interpreting soil test results to determine the minimum fertility needed to reach the stated yield goal.
- ► Considering and testing alternative fertility sources, for example, feedlot manure and municipal sludge or green manure crops overseeded in cereals.

Pest management strategies. Popularity of integrated pest management has provided evidence that complex systems based on understanding pests and their interactions with crops are viable alternatives to automatic use of chemical pesticides. This approach describes "management" as opposed to "control." A number of publications describe these options (*14, 22*). Some specific examples include the following:

- ► Calculating economic thresholds for each potential weed, insect, or pathogen problem and spraying chemicals only when necessary.
- ► Delaying chemical pest control measures until other more benign strategies have failed, for example, rescue treatments for weeds or insects only when they appear.
- ► Using crop rotations to break reproductive cycles of crop pests, for example, corn/alfalfa or corn/soybeans to control corn rootworm.
- ► Rotating pesticides and using minimum effective doses to reduce pressure on pests to develop more virulent forms.
- ► Planting genetically resistant varieties that will tolerate some damage by insects or pathogens.
- ► Maintaining maximum genetic diversity within the field and even within a variety to reduce likelihood of a serious pest problem.

Tillage options. New planting equipment and primary tillage options have opened the opportunities for reducing passes of machinery across the field. Some farmers use permanent ridges and no primary land preparation after the system has been

established. Reduced tillage has become the norm in the Midwest, now practiced on about 80 percent of row-crop acres (*6*). Tillage options include the following:

► Zero-tillage planting into previous crop residues, using large coulters or rotary equipment to open the planting strip.

► Undercutting crop residue with a chisel, rod weeder, or V-blade to control germinated weeds and keep residue on the surface.

► Ridge tillage in a permanent traffic pattern, with or without herbicide banded over the row for early season weed control.

► Minimizing compaction by timely field operations and avoiding wet fields with heavy equipment.

Crop rotation and systems design. Diversity in species is a characteristic of natural ecosystems, and we generally believe that this contributes to their stability (*23*). The opposite extreme in a diversity continuum is the genetic uniformity of monocultural corn cultivation. Farmers have planted corn because it has been profitable, for example, but changing realities suggest that it may not always be the best alternative. More diverse systems may be more sustainable (*11*):

► Rotating corn and soybeans to provide fertility to the cereal and boost yields of both crops; but this may increase potential for erosion from soybean land.

► Using longer, more complex rotations for example, corn, soybean, corn, oat/clover, for more diversity and potential for stability.

► Implementing contour cultivation, permanent ridges, and alternating strips of different crops to diversify the landscape and help reduce erosion.

► Relay- or double-cropping systems to keep a green cover over the land for more of the total year and increase total crop production.

► Overseeding legumes or grasses to capture nitrogen, reduce wind or water erosion of soil, and help recycle nutrients.

► Introducing more diverse enterprises to provide raw material for different value-added products that can enhance income of farms and communities.

Information as a key internal resource. Although different from other production inputs, such as a sack of fertilizer or a container of pesticide, information and experience are truly unique types of resources for decision-making and management. In fact, once information is received and processed, even when it comes from outside the farm, this becomes integrated into the farmer's knowledge and experience base; thus, it is converted into an internal resource (*17*). Some of the unique qualities of information include the following:

► Information is adaptable and can be used in one or more different farming systems or crop applications.

► This resource can be substituted for another, more expensive input, for example, groundwater nitrate in the well at 20 parts per million could mean 100 pounds per acre nitrogen on the irrigated corn crop; this information is worth $15 to $20 per acre.

► Information is mobile; it can be moved from one farm or field to another and shared with neighbors without reducing its value.

► Once applied in the field, information is not "used up" in the same manner as fertilizer or pesticide; in fact, it grows more valuable with use.

Some producers consider information their most valuable internal, renewable resource. In research and extension, we have to provide credible results in a format that can be easily understood and evaluated. With new participatory methods of research and testing, farmers can help in the evaluation and spread of new ideas and practices. One of our greatest challenges today is to provide tools and guidelines that will help growers sort out the available information and make rational and profitable decisions on how and when to use inputs. We need to help farmers empower themselves to gain confidence in appropriate technologies and in science and to make their own decisions about how to achieve a sustainable agriculture.

Conclusions

Midwest farmers are faced with difficult decisions in the use of alternative technologies and new products. The current interest in low-input, sustainable agriculture is a result, in part, of economic factors and, more important, the growing concern about finite energy resources and environmental impacts of some current conventional farming practices and systems. Substituting information, management, and new alternatives for conventional products is one of the ways farmers in the Midwest are addressing these challenges. Agriculture must become more efficient in using inputs; reducing purchased products based on fossil fuels is one way to make production systems more self-sustaining and geared toward future resource realities.

The practices described here are only some of the approaches Midwest farmers use today to move their operations into a more resource-efficient and sustainable mode. The term "low-input" may be an unfortunate choice because of implications of low output and low management; in fact, yields may be the same or could increase as a result of improved management, and low-input could mean high profits. The philosophy of sustainable agriculture is likely to guide our industry into the next century.

REFERENCES CITED

1. Agronomy Extension Specialists. 1987. *Sustainable agriculture...wise and profitable use of our resources in Nebraska.* Dept. Agron., Coop. Ext. Sys., Univ. Nebr., Lincoln. 220 pp.
2. American Society of Agronomy. 1989. *Decisions reached on sustainable ag.* Agron. News, (Jan.): 15.
3. Bezdicek, D. F. 1984. *Organic farming: Current technology and its role in a sustainable agriculture.* Spec. Publ. 46. Am. Soc. Agron., Madison, Wisc. 192 pp.
4. Brown, L. R. 1989. *State of the world 1989.* Worldwatch Inst., Washington, D.C., and W. W. Norton & Co., New York, N.Y.
5. Council for Agriculture Science and Technology. 1988. *Longterm viability of U.S. agriculture.* Rpt. No. 114. Iowa State Univ., Ames. 48 pp.
6. Dickey, E. C., editor. 1986. *Conservation tillage proceedings.* No. 5. Dept. Agr. Eng., Univ. Nebr., Lincoln.
7. Edens, T. C., C. Fridgen, and S. L. Battenfield, editors. 1985. *Sustainable agriculture and integrated farming systems.* Mich. State Univ. Press, East Lansing. 344 pp.
8. Edwards, C. A. 1988. *The concept of integrated systems in lower input/sustainable agriculture.* In C. A. Francis and J. W. King [eds.] *Sustainable Agriculture in the Midwest.* Coop. Ext. System, Univ. Nebr., Lincoln.
9. Edwards, C. A., R. Lal, P. Madden, R. H. Miller, and G. House. 1990. *Sustainable agricultural systems.* Soil and Water Cons. Soc., Ankeny, Iowa.
10. Francis, C. A. 1989. *Breeding hybrids and varieties for sustainable systems.* In C. A. Francis, C. A. Flora, and L. D. King [eds.] *Sustainable Agriculture for Temperate Zones.* John Wiley & Sons, New York, N.Y.
11. Francis, C. A., C. A. Flora, and L. D. King, editors. 1989. *Sustainable agriculture for temperate zones.* John Wiley & Sons, New York, N.Y.
12. Francis, C. A., and G. Youngberg. 1989. *Sustainable agriculture—an overview.* In C. A. Francis, C. A. Flora, and L. D. King [eds.] *Sustainable Agriculture for Temperate Zones.* John Wiley & Sons, New York, N.Y.
13. Francis, C. A., and J. W. King. 1988. *Cropping systems based on farm-derived, renewable resources.* Agr. Systems, U.K. 27: 67-75.
14. Grainger, M., and S. Ahmed. 1988. *Handbook of plants with pest control properties.* John Wiley & Sons, New York, N.Y. 469 pp.
15. Harwood, R. R. 1988. *History of sustainable agriculture: U.S. and international perspective.* In C. A. Edwards et al. [eds.] *Sustainable Agricultural Systems.* Soil and Water Cons. Soc., Ankeny, Iowa.
16. Hoeft, R. G., and E. D. Nafziger. 1988. *Sustainable agriculture.* In R. G. Hoeft [ed.] In Proc., 1988 Ill. Fer. Conf. Dept. Agron., Univ. Ill., Urbana. pp. 7-11.
17. King, J. W., and C. A. Francis. 1988. *Back to the future: The power of communication and information.* Farming Systems Res./Ext. Symp. Univ. Ark., Fayetteville. 19 pp.
18. Lockeretz, W., 1988. *Open questions in sustainable agriculture.* Am. J. Alternative Agr. 3: 174-181.
19. Potash and Phosphate Institute. 1989. *The challenge of groundwater concerns with production agriculture—is LISA the answer?* Fertilegrams. Atlanta, Ga.
20. Power, J. F., editor. 1987. *The role of legumes in conservation tillage systems.* Soil and Water Cons. Soc., Ankeny, Iowa.
21. U.S. Department of Agriculture. 1980. *Report and recommendations on organic agriculture.* Washington, D.C. 94 pp.
22. Ware, G. W. 1980. *Complete guide to pest control, with and without pesticides.* Thompson Publ., Fresno, Calif. 290 pp.
23. Wilson, E. O., ed. 1988. *Biodiversity.* Nat. Acad. Press, Washington, D.C. 521 pp. □

CROP ROTATIONS
Sustainable and profitable

By Roger L. Higgs, Arthur E. Peterson, and William H. Paulson

THE time-tested advantages of crop rotations and the goals of low-input, sustainable agriculture are synonymous in most respects. Crop rotations are basic to the manner in which many farmers practice low-input, sustainable agriculture. Sustained profitability with either rotations of sustainable agricultural systems is a necessary assumption if farmers are to adopt these systems.

Rotations and sustainable agriculture are really old agricultural practices. In the 1940s and 1950s, agriculture began the transition toward a more intensified monocultural system of cropping over vast areas of land, with high inputs of a fossil-fuel-based technology. This technology uses an impressive array of fertilizers, other agricultural chemicals, fuel, and equipment. Producers believed that the benefits from rotations would be supplanted by this new, rapidly developing technology and monocultural cropping system. Changes in the agricultural economy, environmental concerns, and results from long-term rotation studies now dictate a renewed and close look at crop rotations.

Rotational pros and cons

Historically, crop rotations are believed to date from the first century B.C. The Morrow plots at the University of Illinois, Urbana, America's oldest experimental field, have provided comparisons of rotations since 1876 (*7*). Other long-term rotation studies in Missouri, western Canada (*8*), Iowa (*5*), and Wisconsin (*4*) have been conducted since 1889, the 1900s, 1915, and 1967, respectively.

The advantages attributed to crop rotations have much in common with the reasons given for considering a low-input, sustainable agricultural management system. Crop rotations have always been a valid farm management practice. The advantages for using a suitable rotation system are many:

► *Reduction in the amount of soil erosion and water runoff.* These problems are more accentuated on erodible soils with the more intensive, monocultural cropping system.

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► *Use of legumes.* The need for commercial nitrogen is reduced for a corn crop following alfalfa or soybeans. Nitrogen is retained for a longer period in the form of organic material, which reduces losses due to leaching and runoff.

► *Improvement of soil tilth.* Soil conditions are improved because of the forage crops in rotations, which improve organic matter content and soil structure, which, in turn, improve infiltration and permeabilty.

► *Weed, insect, and crop disease cycles are broken by the use of cropping sequences that reduce the need for pesticides, both in kinds and amount.*

► *Positive allelopathy effects.* The residues of some crops stimulate subsequent crops in certain crop sequences. Wheat residue improves corn yields, and vice versa. Conversely, alfalfa residue is auto-toxic to alfalfa that is replanted in its residue.

► *Diversificiation.* Different crops on a farm help distribute time and labor requirements throughout the year and should reduce the power requirement of the principal tractor used for tillage.

► *Value-added potential.* Home-grown crops can be used to feed owned livestock. The value of the crop is increased because of the marketing of livestock products sold in the development of a holistic farming system. Livestock manure also is returned to the land, which reduces the dependency upon commercial fertilizer.

There are also disadvantages associated with crop rotations. Disadvantages would favor monocultural cropping systems:

► *The need for a greater variety of machinery with a higher cost per crop unit produced.* Machinery may not be used as efficiently as it would be in a single-crop system.

► *The farm manager needs a broader knowledge base and more varied expertise that is required when managing a greater number of crops.* This may be a particular burden on part-time farmers.

► *Financial returns may be lower in certain years.* Not all cropland would be available to take advantage of particularly favorable market conditions of a specific crop. However, income may be more uniform because the peaks and valleys associated with a single crop could be evened out.

► *Growing conditions in a given year or region may favor one crop over another.* Diversification may even out production highs and lows. Conversely, certain climates and locations may favor monocultures.

Clearly, the goals for sustainable agriculture relate to the use of crop rotations. The objectives of both that interrelate and are mutually advantageous include:

► *Reduction of soil erosion.*

► *Protection of groundwater and surface water;* a reduction in the need for pesticides, commercial fertilizer, and less-intense cropping systems should improve water quality.

► *Reduction of tillage;* consequently, less fossil fuel will be required.

► *Reduction in the use of pesticides and fertilizer.*

► *Promotion of healthier population.*

► *Promotion of farm profitability, production efficiency, and sustainability of the family farm.*

What of new technology?

Should a change from monoculture to crop rotations require that the farmer disregard technological advances that have occurred since the 1940s and 1950s? Farmers should consider using the positive information and technology available. For instance, varietal improvements have occurred in all crops. Use of older varieties would not change the environmental impact and would reduce farm profitability. In another instance, both monoculture and rotations need some additional fertility. A lesson learned from the Morrow plots is that soil nutrients will be depleted by all crop sequences or rotations over time without the addition of fertilizer or manure. In a study initiated in

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1876, corn yields averaged 42 bushels per acre for continuous corn, 58 bushels per acre for a corn-soybean rotation, and 76 bushels per acre for a corn-oats-alfalfa rotation when no fertilizer was applied. Since 1955, part of each rotation was given an annual application of nitrogen-phosphorus-potassium fertilizer. Yields of the three respective rotations averaged 124, 130, and 134 bushels per acre. Manure, lime, and phosphorus added to other selected plots increased production in continuous corn to 89 bushels per acre, in the corn-soybean rotation to 124 bushels per acre, and in the corn-oats-alfalfa rotation to 136 bushels per acre. Manure could certainly substitute for some of the additional fertilizer needs, but the quantity of manure available would be insufficient in the United States to meet the total needs at current crop production levels.

From another perspective, many farmers who practice sustainable agricultural techniques and use crop rotations likely will make wise use of appropriate, low-risk herbicides, insecticides, and fungicides. Presently, 95 percent of U.S. farmers apply herbicides to corn and soybeans. It seems unlikely that substantial numbers of farmers would totally quit using herbicides.

In relation to pesticide use in rotations, cycles are broken by crop rotation for the build-up of certain insects, diseases, and weeds. The break-up of these cycles for some pests will reduce the need for pesticides in many instances. For example, the corn rootworm is seldom a problem for corn during the year following alfalfa in a rotation. Regarding diseases, soybean stem rot is controlled by crop rotation. Weeds, such as wild oats, wild proso millet, and fall panicum, are problems in monocultures and, conversely, controlled better in rotations.

Rotation systems will continue to rely upon mechanized systems. Fuel requirements can be reduced by using conservation tillage practices as part of planting systems in crop rotations.

The matter of profitability

Financial profitability of a cropping system is essential for the livelihood of the farmer and the farm family. Crop rotations and low-input, sustainable agriculture must return an acceptable profitability level if farmers are going to adopt such systems. The acceptable level of profitability will vary among farmers and relates to various social, religious, and family values.

Several recent studies in Canada and the United States that make economic comparisons among crop rotations indicate that profitable choices can be made (*1, 3, 6, 8*). Six crop sequences were compared in a 10-year economic analysis, 1977-1986, at Lancaster, Wisconsin.[1] The crop sequences were continuous corn, corn-soybeans-corn-oats-alfalfa, corn-corn-oats-alfalfa-alfalfa, corn-corn-corn-alfalfa-alfalfa, corn-corn-alfalfa-alfalfa, and continuous alfalfa. Nitrogen was applied at four different rates to corn in the rotations.

The economic analysis was determined for a 400-acre farm using actual crop yield data from 1977-1986 (see table). The economic analysis was an historic analysis in that actual yields, actual annual average Wisconsin prices (no government programs), actual levels of seed and chemical inputs, and actual field passes with equipment were used. Machinery and in-field labor costs were based upon operations on a 400-acre farm. The base data are in 1986 dollars, with adjustments made for 1976-1985 using appropriate indices. No land or management costs were deducted. Phosphorus and potassium input costs were based upon crop removal. Harvesting was assumed to be performed by the farmer, except that custom rates of $20 per acre were charged for harvest of corn in the continuous corn rotation, soybeans, and oats. Alfalfa seeding was charged in the year of its original seeding. Profit referred to in this study means the economic return to land and management.

[1]Higgs, R. L., J. Ambrosius, A. Peterson, R. Klemme, W. Paulson, and S. McComb. 1987. "Economic Returns for Six Long-Term Rotations in the Upper Mississippi Valley." Paper presented at the 42nd annual meeting, Soil Conservation Society of America.

The cash crop values used to derive profits in this study do not consider the enhanced value of these crops when home-fed to livestock. Crop rotation profits of $10,000 to $12,000 for rotations with primarily corn and alfalfa would be potentially enhanced in value on a livestock farm, to $15,000 to $20,000 per year. Continuous corn or continuous hay would not provide a complete ration of home-grown crops.

Economic comparisons of two-year crop rotations that included alfalfa-corn, soybean-corn, and corn-corn in Minnesota (*3*) showed that an alfalfa-corn sequence, with the alfalfa subjected to a three-cut system, is the economically optimum rotation when compared to continuous corn or soybean-corn systems. In western Colorado (*1*), a rotation that included alfalfa and sugarbeets is most profitable, partially because continuous corn required more nitrogen fertilizer.

Profit per year for six Upper Midwest crop rotations on a 400-acre farm, based on a 10-year study (1977-1986) at Lancaster, Wisconsin

Rotation	Annual Profit by Nitrogen Application Rate (pounds/acre) for Corn			
	0	50	100	200
	$			
Continuous corn	-21,888.00	19,504.00	28,632.00	32,096.00
CSCOA*	-8,120.00	-5,388.80	-4,076.00	-5,843.20
CCOAA	5,205.60	9,772.00	8,759.20	4,488.80
CCCAA	965.60	7,717.60	10,631.20	3,716.80
CCAA	11,280.00	11,691.00	12,779.00	4,837.00
Continuous alfalfa	19,864.00	18,516.00	20,720.00	18,760.00

*C=corn, S=soybeans, O=oats, and A=alfalfa.

Average total revenues and costs from 1977 to 1986 under U.S. market and government support scenarios in a 10-year study, Lancaster, Wisconsin

Crop Sequence	Historic Market Scenario		Government Program Scenario	
	Average Total Revenue	Average Total Cost	Average Total Revenue	Average Total Cost
	$/acre			
AAAAA	276.33	163.89	276.32	163.89
CCCCC	282.73	212.37	303.28	197.74
CCOAA	272.22	207.29	282.49	201.22
CCAA	280.61	224.51	292.80	220.28
CCCAA	272.78	230.47	286.52	227.76
CSCOA	251.00	237.98	259.18	231.41

*A=alfalfa, C=corn, O=oats, S=soybeans.

The effect of government programs on profit levels in crop sequences was also assessed for the 10-year Lancaster, Wisconsin study.[2] Data from these studies showed that continuous corn produced the highest average revenues, while continuous alfalfa had the lowest average production costs. Thus, continuous alfalfa and continuous corn ranked first and second as the most profitable systems. It should be noted that corn sale prices were very favorable in the 1970s and hay prices were very favorable in the 1980s. Continuous corn received the greatest profit enhancement ($35.16 per acre) because of government programs, whereas continuous hay received no government support.

Rotations of primarily corn and hay (corn-corn-oats-alfalfa-alfalfa, corn-corn-corn-alfalfa-alfalfa, corn-corn-alfalfa-alfalfa) showed moderate profitability on 400 acres ($7,717 to $12,779 range) for the 50 and 100 pound-per-acre nitrogen application level. The corn-corn-alfalfa-alfalfa rotation with no nitrogen fertilization showed a net profit of $11,280 for 400 acres.

Research in Iowa in 1952 (*2*) indicated that continuous corn provided more return for a 100-acre farm, using 1947 prices, than would a corn-oats-legume rotation because of the favorable prices for corn versus forages. This post-World War II report from Iowa was indicative of later research reports and farmers' experiences in major cropping regions.

[2]McComb, S., R. Klemme, and J. Ambrosius. 1988. "The Effect of Government Programs on Profit Levels and Variance in Rotation and Continuous Cropping Systems, 1977-1986." Paper presented at the American Agricultural Economic Association Annual Meeting.

Crop yields (bushels/acre adjusted to 15.5% moisture) for a crop sequence study, 1977-1986, at Lancaster, Wisconsin

	Crop Yields at Various Nitrogen Application (pounds/acre) Levels				
*Cropping Sequence**	*0*	*50*	*100*	*200*	*Average*
	bushels/acre				
Corn yields					
Continuous corn	36.5	88.1	103.1	125.3	88.3
cSCOM†	119.4	128.1	130.0	130.0	126.9
CScOM	115.1	125.9	134.2	131.3	126.6
cCCMM	131.3	133.9	139.6	132.8	134.4
CcCMM	92.5	118.5	129.4	128.5	117.2
CCcMM	71.4	109.8	123.6	125.8	107.6
cCOMM	131.1	138.4	138.2	138.0	136.4
CcOMM	100.5	124.0	133.1	133.4	122.8
cCMM	135.3	142.3	143.0	136.9	140.3
CcMM	106.1	122.7	138.3	135.2	125.5
Average	104.4	123.9	131.4	131.8	122.8
Oat yields					
CSCoM	38.6	49.7	59.7	70.9	54.7
CCoMM	54.2	64.7	67.7	75.2	65.4
Average	46.0	55.3	63.0	71.5	58.9
Soybean yield					
CsCOM					
Average	37.9	38.8	39.6	40.1	39.2
	tons/acre dry matter				
Alfalfa yields					
CSCOm	4.31	4.17	4.06	4.42	4.24
CCCmM‡	1.79	1.78	1.90	2.01	1.88
CCOMm	4.40	4.38	4.49	4.58	4.47
CCOmM	4.06	4.06	4.09	3.97	4.04
CCOMm	4.29	4.39	4.39	4.24	4.32
CCmM	1.36	1.95	2.11	2.05	2.01
CCMm	4.55	4.37	4.55	4.65	4.53
Continuous meadow	3.76	3.69	3.82	3.69	3.75
Average	3.64	3.60	3.68	3.71	3.66

*C = corn, S = soybeans, O = oats, M = meadow.
†Lower case letters indicate the crop year in which the yield was determined.
‡Direct seeded annually from 1977 through 1986. The continuous meadow was reseeded (direct) in 1980 and 1986. Two cuttings were obtained in the continuous meadow in 1980 and 1986.

Two Canadian studies in Ontario and Saskatchewan (*6, 8*) noted economic results of crop rotation studies similar to those in the United States. When grain prices were high for monoculture or row crops, such as wheat, corn, or soybeans, there was more profit in continuous cropping or in rotations dominated by these crops. Six crop sequences that incorporated the six principal Ontario field cash crops (*6*) were compared over a 20-year period under five alternative yield-trend scenarios. The economically preferred sequence under all five yield-trend scenarios was continuous corn, with corn-soybeans a close second. The corn-alfalfa sequences ranked fourth or fifth in economic return.

Various combinations of wheat and fallow rotations were compared in south-western Saskatchewan for 18 years (*8*). When wheat prices were low, the fallow-wheat rotation was the most profitable. When prices were moderate, the fallow-wheat-wheat rotation provided the highest net return. When prices were high, continuous wheat provided the highest net return.

Conclusions

Crop rotations that include grain and forage crops can be profitable and contribute to a sustainable agriculture. The relative prices of grain and forage and the costs of producing cash crops become important in determining which combination of forages and other crops pays the farmer the best. Changing public attitudes regarding soil and water quality and tougher environmental and soil erosion laws likely will favor crop rotations over monocultures.

REFERENCES CITED

1. Gee, C. K., and C. W. Robinson. 1969. *The economics of cropping systems for western Colorado.* Bull. 539S. Colo. Agr. Exp. Sta., Ft. Collins.
2. Heady, E. O., H. Jensen, and M. Anderson. 1952. *How to choose the most profitable crop rotation for your farm.* Iowa Farm Sci. 6: 191-195.
3. Hesterman, O. B., C. C. Sheaffer, and E. I. Fuller. 1986. *Economic comparisons of crop rotations including alfalfa, soybean, and corn.* Agron. J. 78: 24-28.
4. Higgs, R. L., W. H. Paulson, J. W. Pendleton, A. E. Peterson, J. A. Jacob, and W. H. Shrader. 1976. *Crop rotations and nitrogen: Crop sequence comparisons on soils of the driftless area of southwestern Wisconsin.* Res. Bull. No. R2761. Univ. Wisc. Agr. Exp. Sta., Madison. 12 pp.
5. Shrader, W. D. 1968. *Crop rotations: 1968 viewpoint.* Iowa Farm Sci. 23: 3-6.
6. Stonehouse, D. P., B. D. Kay, J. K. Baffoe, and D. L. Johnston-Drury. 1988. *Economic choices of crop sequences on cash-cropping farms with alternative crop yield trends.* J. Soil and Water Cons. 43: 266-270.
7. Welch, L. F. 1976. *The Morrow plots—one hundred years of research.* Ann. Agron. 27: 881-890.
8. Zentner, R. P., and C. A. Campbell. 1988. *First 18 years of a long-term crop rotation study in southwestern Saskatchewan—yields, grain protein, and economic performance.* Can. J. Plant Sci. 68: 1-21. □

Low-input farming systems under conservation compliance

By Dana L. Hoag and Kevin E. Jack

THE Food Security Act of 1985 (FSA) broke new legislative ground by establishing unique programs to address environmental concerns. It attacks soil conservation with the conservation compliance, conservation reserve, and sodbuster programs; agri-chemical pollution is addressed with research and extension programs to promote low-input farming systems. It may be difficult, however, to achieve soil conservation and reduce inputs simultaneously because conservation systems are not always consistent with low-input agriculture.

Low-input agriculture is to a large degree linked to conservation plans developed for conservation compliance because these plans affect input decisions. Policymakers, agricultural advisors, and farmers should consider input use in conservation plans if low-input agriculture is deemed important for society. Although soil conservation compliance will be the dominating concern, unnecessary tradeoffs might be reduced with a comparative assessment of the impact on resources and the environment for every soil conservation system.

In this analysis, the effect of conservation compliance on the adoption of low-input, sustainable agriculture is examined for Stanly County, North Carolina. For illustration, low-input, sustainable agriculture is defined as a system that uses no commercial fertilizer or pesticides. These results illustrate general relationships that may vary in individual situations or interpretations of what constitutes such a system.

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Stage set for conflict

The conservation compliance provision of the Conservation Title (Title XII) denies virtually all government program benefits to persons who produce an agricultural commodity (annual crop) on a highly erodible field after January 1, 1990, without an approved conservation plan (*8*). These benefits include price and income supports, disaster payments, crop insurance, Farmers Home Administration loans, Commodity Credit Corporation storage benefits, farm storage facility loans, and other programs with payments made for commodities produced by the farmer. Producers had until January 1990 to secure plan approval from the Soil Conservation Service (SCS) and have until 1995 to implement the plan fully.

Subtitle C of the FSA authorized the creation and funding of research and education to promote the development and adoption of low-input farming techniques. Although first authorized in 1985, Subtitle C was not funded until fiscal year 1988, when an initial allocation of $4.1 million was granted (*22*). Subtitle C emphasizes practices that (1) enhance agricultural productivity; (2) maintain the productivity of the land; (3) reduce soil erosion and loss of water and plant nutrients; and (4) conserve energy and natural resources. Such agricultural practices often exclude or largely reduce the use of synthetically derived fertilizers and pesticides while relying upon crop rotations, crop residues, legumes, green manures, mechanical cultivation, mineral-bearing rocks, and aspects of biological pest control to maintain soil productivity (*20*). In addition to its environmental aspects, mounting concern about farm financial stress and the associated need to reduce cash outlays have prompted producer interest in low-input farming systems (*4, 22*).

Title XII and Subtitle C appear mutually compatible. Each seeks to promote the use of agricultural systems having reduced off-farm costs and, in doing so, addresses particular criticisms of previous agricultural legislation. For example, Title XII is "in part, a response to the charge that price support programs have contributed to soil erosion by encouraging production of soil-depleting crops and by making it profitable for farmers to cultivate marginal land" (*18*). Similarly, it has been asserted that "U.S. farm-commodity programs encourage conventional farming systems and discourage low-input systems" (*23*). Madden noted that "federal price support policies...effectively discourage many farmers from producing forage legume crops that would...reduce the farmer's dependence on purchased inputs of fertilizers and pesticides" (*14*). The enactment of Subtitle C may be viewed, in part, as a response to this criticism.

Unfortunately, soil conservation systems are not always low-input systems. For example, conservation tillage technologies that reduce erosion sometimes increase the use of fertilizers, pesticides, and other farm chemicals (*5*). Madden noted, "The herbicides used in lieu of tillage to control weeds have become a major source of environmental damage in many instances" (*14*). Buttel and Gillespie found "many organic (low-input) farmers will be reluctant to use reduced-tillage practices because these practices tend to require use of herbicides" (*3*). Also, conservation tillage systems rely on herbicides that are more likely to remain on the soil surface than to bind with soil particles, making chemical runoff into the en-

vironment an issue (*16*). Low-input farming systems often rely heavily on mechanical cultivation to replace chemical herbicides; mechanical cultivation practices may lead to unacceptable levels of soil loss under the provisions of conservation compliance.

The conflict of goals found in the FSA is not unexpected considering the multitude of objectives outlined in the legislation. Referring specifically to the conservation aspects of FSA, Reichelderfer commented, "...when a program has multiple goals, no single goal is likely to be maximized without trading off performance in achieving another goal or goals" (*17*). Madden noted that while conservation tillage "is highly effective in attaining one goal of sustainability, it is contrary to other goals, including reduction of environmental hazards and human health risk associated with use of synthetic chemical pesticides" (*14*).

Farm-level considerations

The decision of agricultural producers to participate in government farm programs and to adhere to conservation compliance rules is highly farm-specific. Individual factors, including soil type, slope and slope length, weather, historical production, current base acreage, and proportion of base to total acreage, will determine whether conservation compliance will be successful in reducing erosion or if farmers will opt to quit using programs to avoid the additional costs imposed by the legislation (*11*). Similarly, these same factors will influence the relative economic attractiveness of low-input farming techniques to agricultural producers.

Generally, low-input systems have not been financially competitive with traditional production systems largely because of the relatively lower prices received for legumes and other crops often used in low-input systems. Commodity programs are partly to blame for price differentials that do not support low-input, sustainable agricultural systems. Commodity programs also encourage monocultures, thereby discouraging the use of rotations.

Farmers received mixed financial signals for low-input agriculture under conservation compliance. Its impact on sustainable agriculture is linked to erosion controls on participants in commodity programs. For some, the erosion constraint will increase the use of hays and legumes in rotation consistently with low-input farming. However, for others who use conservation tillage to control erosion agrichemical use could increase. Of course, there are several exceptions specific to the agriculture and personal circumstances of any particular producer.

Perhaps the greatest economic disincentive to producer adoption of low-input systems is the opportunity cost of lost commodity program payments. A producer must add the opportunity cost of lost base acreage to the cost of the low-input system. Base is the farm's historical acreage that determines total payments to the farm. For example, a two-year rotation of corn and soybeans uses 50 percent corn base on an average annual basis. A 100-acre farm with 75 acres of base would lose 25 acres of base if a corn-soybean rotation were adopted. Low-input, sustainable agricultural systems that do not have a program crop on every acre each year might be avoided by farmers with a large proportion of base acreage.

Low-input in North Carolina

It is helpful to examine a local example to understand better how conservation compliance might affect adoption of low-input, sustainable techniques. A study recently conducted in Stanly County, North Carolina, looked at the linkage between conservation compliance and low-input adoption on a composite 100-acre farm (*9*). Stanly County is typical of southeastern U.S. Piedmont. More than 90 percent of the county's 1987 harvested acreage was devoted to six major field crops: corn, soybeans, wheat, oats, barley, and grain sorghum (*15*). Much of the wheat, oats, and barley is double-cropped with soybeans or grain sorghum.

Soil erosion is an important issue in Stanly County. More than 80 percent of the total land area is classified as either highly erodible or potentially highly erodible. SCS, according to officials in the agency's North Carolina state office, will treat potentially highly erodible soils as highly erodible unless a farmer appeals, thus making conservation compliance legislation an important consideration for most agricultural producers.

The optimal crop plans and decision to participate in government programs were analyzed for three levels of program base: 25, 50, and 100 percent of total farm acres. Because farmers are free to trade base acreages between program crops on a one-time basis (except from other crops to cotton) as they develop their conservation plans, the farm was restricted only to its total base acreage. This base could be distributed freely between program crops in the most profitable manner.

The optimal crop mix and program participation decisions were analyzed for each level of program base acreage, with and without conservation compliance. The model farms could chose among 11 agricultural systems representing a diversity of continuous and rotation cropping patterns, erodibilities, agrichemical intensity, and purchased chemical fertilizer use. The 11 systems included three rotations and two continuous crops. The three rotations were corn followed by soybeans; a four-year cycle with hay grown for two complete years, corn the following year, and soybeans in the fourth year; and corn followed by a wheat-soybean double-crop.

Relative erosiveness, fertilizer use, and pesticide use of systems analyzed

		Conventional Crops			*Low-Input Crops*		
System	*Crop(s)*	*Relative Erosiveness**	*Relative Chemical Fertilizer Requirement**	*Relative Pesticide Requirement**	*Relative Erosiveness**	*Relative Chemical Fertilizer Requirement**	*Relative Pesticide Requirement**
Rotation	Corn-soybean	High	Moderate	High	High	None	None
Rotation	Corn-wheat/soybean	Low	High	High	Moderate	None	None
Rotation	Hay-hay-corn-soybean	Low	Low	Moderate	Low	None	None
Continuous	Corn	High	High	High	High	None	None
Continuous (no-till)	Corn	Low	High	High	—	—	—
Continuous	Soybean	High	Low	Moderate	High	None	None

*Denotes comparison over all 11 systems.

Each rotation uses two sets of practices: conventional production practices and low-input techniques. Rotation 1 has a conventional production system of conventionally tilled corn and soybeans grown with pesticides and nitrogen fertilizer, and a low-input system using mechanical cultivation, poultry litter for fertlizer, and a crimson clover winter cover preceding corn and a rye winter cover preceding soybeans.

Rotation 2 has a sequence of mixed grass/legume hay, no-till corn, and no-till soybeans, all grown with typical levels of purchased chemical fertilizer and pesticides, and a low-input system of grass hay, no pesticides, mechanical cultivation, and poultry litter applied for nitrogen.

Rotation 3 has one treatment using no-till corn and a conventionally tilled wheat/no-till soybean double-crop; the other, a low-input sequence, includes corn followed by a double-crop of conventionally tilled wheat and soybeans, with poultry litter applied to the corn and wheat. These three rotations provide a total of six cropping systems.

Corn and soybeans were the only continuous crops analyzed. The three continuous corn systems included both no-till and conventional tillage systems using standard levels of fertilizer, insecticide, and herbicide and a low-input cultivation system relying on no purchased fertilizers or pesticides, with poultry litter and crimson clover providing nitrogen. Two continuous soybean cropping systems also were analyzed. Conventional tillage practices and standard levels of purchased inputs were used in one system; the other had no purchased inputs, relying exclusively on mechanical cultivation for weed control and poultry litter for fertilizer.

All low-input systems were charged for liming and manure application. Addition of lime was found to be important in previous low-input corn and soybeans trials conducted in the Piedmont (*2, 13*). Stockpiled poultry litter is readily available in Stanly County and has been recognized as a valuable source of nutrients, especially when incorporated into the soil (*1, 19*).

The erodibility of the soil under each cropping system, as measured by the cover management (C) factor, was obtained from the universal soil loss equation guidebook for North Carolina (*21*) or, where these were not available, from calculations made by SCS personnel.

Soils information is from the Stanly County soil survey. Baseline yield estimates by soil type are averages weighted by percent of total county land area in each soil classification multiplied by the estimated yield for that soil. Information about the effect of low-input practices on crop yield by soil type was not available. However, a comparison over several studies showed a reasonably consistent decline of 10 percent in corn yields for low-inut systems and no reduction in soybean yields nationally.[1] Yields were adjusted upward for no-till corn and downward for crops grown continuously and for low-inut corn. Therefore, no-tillage rotation crops had the greatest yield advantage, while low-input monocultures experienced the greatest yield disadvantage. Low-input rotation crops yielded similarly to conventional corn in a monoculture.

Net returns to land, management, and risk for conventional and low-input, sustainable cropping systems in Stanley County, North Carolina*

System	Crop(s)	Conventional Crops		Low-Input Crops	
		Before Program Payments	After Program Payments	Before Program Payments	After Program Payments†
		$/acre			
Rotation	Corn-soybean	8	27	9	28
Rotation	Corn-Wheat/soybean	45	87	70	104
Rotation	Hay-hay-Corn-soybean	37	48	37	48
Continuous	Corn	−10	27	−4	28
Continuous (no-till)	Corn	22	67	—	—
Continuous	Soybean	−1	−1	43	43

*Based on a composite farm with soils similar to farms in Stanly County.
†Net benefits after set-aside costs.

Production costs were calculated for each system based on information collected from state extension specialists, North Carolina agricultural extension service field crop budgets, and previous economic research in Stanly County (*10*). The production practices and input levels are typical for Stanly County. Cost figures include only direct variable costs and interest on operating capital, and they reflect current input prices. It was assumed that farmers receive no government program benefits other than deficiency payments. Commodity prices, government target prices, and set-aside requirements are averages of those forecasted by the Food and Agriculture Policy Research Institute (FAPRI) for 1989-1990 to 1994-1995 (*7*).

Stanly County results

Conservation compliance did indeed influence the projected profitability of low-input agriculture in Stanly County. A farm with 100 percent of its cropland in program base would earn the most by participating in government commodity programs regardless of conservation compliance cropping restrictions. The relative benefit of commodity programs was large compared to compliance costs, and both the best low-input, sustainable and conventional systems used all of the farm's base. However, the most profitable system, which was a low-input, corn-wheat/soybean rotation, was no longer optimal with the introduction of conservation compliance because it exceeded the maximum allowable soil loss limit. The conventional corn-wheat/soybean rotation was the most profitable system meeting conservation compliance rules.

The only low-input system meeting the erosion limit, hay-hay-corn-soybeans, was less profitable than the conventional corn-wheat/soybean rotation primarily because it did not use all of the farm's base. For example, the per-acre return for the hay-hay-corn-soybean rotation was $48. Eleven dollars were from government payments. The more profitable conventional corn-wheat/soybean system earned $87, including $42 from government payments. The hay rotation used only 25 percent of the farm's base, while the corn-wheat/soybeans system used 100 percent.

If the corn-wheat/soybean option were not available, no-till corn would be the most profitable conservation system. If a policy were implemented to remove the $45 program payment advantage for corn, low-input soybeans would be more profitable. However, this system would require the farmer to exit commodity programs because low-input soybeans result in highly erodible soils. Therefore, with corn receiving more favorable benefits compared to low-input, soil conservation wins out over low-input; without this favorable treatment, low-input is more profitable than soil-conserving no-till corn. For this example, soil conservation

[1]Holloway, Herb A., and Dana L. Hoag. 1989. "Goals and Methods of Low-Input Sustainable Agriculture: Implications for Economics." Paper presented at the Southern Agricultural Economics Association meeting, Nashville, Tennessee.

and reduced input use through low-input are at odds. Even a program to equate low-input and corn payments would not alter this.

It was most profitable for the farms with 50 and 25 percent of total cropland in program base to drop out of government commodity programs completely and to grow 100 acres of the low-input, corn-wheat/soybean rotation. These results occurred at each level of base acreage, both with and without conservation compliance rules in effect. In these cases, the low-input crop used too much base to be allowed on the whole farm. More money is earned by devoting all acreage to the low-input, corn-wheat/soybean rotation and receiving revenues only from crop sales than would be realized by restricting the acres of rotation and receiving government payments.

Although it is not profitable to use commodity programs on farms with 25 or 50 percent base acreage, the hay rotation is relatively more competitive with continuous corn and the corn-wheat/soybean system than before because it can be used on all 100 acres without exceeding base acreage limits. The other systems could be grown on only one-half or one-quarter of the acreage because they use an acre of base for each acre of the system. Therefore, low-input rotations are more competitive on farms with relatively little base acreage.

Summary and conclusions

Conservation compliance can affect adoption of low-input systems. While both reduced inputs and reduced erosion are goals of the Food Security Act, only erosion is addressed through conservation compliance. Therefore, erosion objectives will be met, but sometimes with unintentional neglect of low-input objectives.

Only those participating in government commodity programs are directly affected by conservation compliance, which addresses certain disincentives for soil conservation in commodity programs. Sometimes, reduced erosion increases the use of low-input, sustainable systems, such as rotations that incorporate grass or legume hays. However, conservation systems are not always low-input systems. For example, many would argue that conservation tillage increases input use and leads to greater water pollution.

Conservation compliance made low-input systems less economial than a soil-conserving conventional system on a composite North Carolina farm with all of its cropland in base. In this example, increased chemical use was traded for reduced soil erosion. However, on a farm with less base, it was profitable to escape conservation compliance by exiting the commodity programs to use a low-input system that resulted in more soil erosion.

When commodity programs are a major part of a farmer's income, conservation systems will be the most important objective, even at the risk of sacrificing a low-input system. However, when the benefits of the program are insufficient to justify compliance, a farmer may switch to any rotation desired. This may or may not motivate a switch to a low-input, sustainable system, but at least the erosion and base restrictions will no longer be imposing a disadvantage on the low-input systems. For farms with relatively little base, conservation compliance will increase the relative profitability of low-input approaches because rotations control erosion but may not be penalized by reduced commodity program receipts.

Our results demonstrate that low-input goals cannot always be achieved when conserving soil, especially because many low-input, sustainable systems rely on tillage to compensate for reduced chemical use. Nevertheless, conservation plans could also contain low-input objectives. The Soil Conservation Service and the Extension Service could revise the alternative conservation systems (ACS) used in conservation planning to meet both objectives. Individual circumstances relevant to each farm operation should dictate the relative importance of each goal. Conservation systems that increase infiltration and use of nitrogen may be inappropriate where groundwater nitrates are a problem. However, systems that increase infiltration may be more appropriate where algae blooms in lakes are troublesome.

SCS and Extension could develop a comparative assessment of the impact on resources and the environment (which we have dubbed CAIRE) for each ACS that warns of possible environmental concerns related to that particular system. The CAIRE's would build awareness and understanding about the relationships between soil conservation systems and other low-input systems without requiring the Extension Service or SCS to impose low-input, sustainable agriculture requirements prematurely before more information is known. Most importantly, the CAIREs encourage more consideration of low-input objectives in a broad sense without interupting or competing with the soil conservation objectives of conservation compliance.

Finally, this study demonstrates only that conflicts can occur. The net outcome of conservation compliance on the use of low-input, sustainable systems is unknown and will depend on all farmers' personal circumstances. Nevertheless, conservation compliance could have a more positive affect on low-input, sustainable approaches if a national plan were instituted to support their joint consideration.

REFERENCES CITED

1. Barker, James C. 1989. *Livestock waste sampling, analysis and calculation of land application rates.* EBAE 111-84. Dept. Bio. and Agr. Eng., N. Car. State Univ., Raleigh.
2. Bergmark, Christine. 1985. *Limited-input corn production for limited-resource farmers in the piedmont, North Carolina.* M.S. thesis, N. Car. State Univ., Raleigh.
3. Butel, Frederick H., and Gilbert W. Gillespie, Jr. 1988. *Preferences for crop production practices among conventional and alternative farmers.* Am. J. Alternative Agr. 3: 11-17.
4. Cacek, T., and L. Langer. 1986. *The economic implications of organic farming.* Am. J. Alternative Agr. 1: 25-29.
5. Council for Agricultural Science and Technology. 1988. *Long term viability of U.S. Agriculture.* Rept. No. 114. Ames, Iowa.
6. Dunphy, E. J. 1986. *1986 soybean on-farm test report.* N. Car. Agri. Ext. Serv., Raleigh,.
7. Food and Agriculture Policy Research Institute. 1988. *FAPRI review—November 1988 10-year baseline.* Univ. Mo., Columbia, and Iowa State Univ., Ames.
8. Hoag, Dana L. 1988. *Handbook on the conservation provisions of the 1985 Food Security Act.* N. Car. Agri. Ext. Serv., Raleigh
9. Hoag, Dana L., and Kevin E. Jack. 1989. *Adoption of low-input systems under conservation compliance.* Working paper, Dept. Econ. and Bus., N. Car. State Univ., Raleigh.
10. Holloway, Herbert A. 1989. *A mixed integer programming model for analysis of the impact of conservation compliance.* M.S. thesis, N. Car. State Univ., Raleigh.
11. Holloway, Herb A., and Dana L. Hoag. 1989. *Farm production decisions under conservation compliance.* Working Paper No. 148. Dept. Econ. and Bus., N. Car. State Univ., Raleigh.
12. Hunter, Carol. 1985. *An agronomic and economic evaluation of limited input soybean production practices.* M.S. thesis, N. Car. State Univ., Raleigh.
13. Madden, Patrick. 1989. *Policy options for a more sustainable agriculture.* In *Increasing Understanding of Public Problems and Policies - 1988.* Farm Foun., Oak Brook, Ill. pp. 134-142.
14. North Carolina Department of Agriculture. 1988. *North Carolina agricultural statistics: 1988.* Raleigh.
15. Papendick, R. I., L. F. Elliot, and R. B. Dahlgren. 1986. *Environmental consequences of modern production agriculture: How can alternative agriculture address these issues and concerns?* Am. J. Alternative Agr. 1: 3-10.
16. Reichelderer, Katherine. 1989. *Policy issues arising from implementation of the 1985 farm bill conservation provisions.* In *Increasing Understanding of Public Problems and Policies - 1988.* Farm Found., Oak Brook, Ill. pp. 15-124.
17. Robinson, Kenneth L. 1989. *Farm and food policies and their consequences.* Prentice-Hall, Englewood Cliffs, NJ.
18. Sims, J. Thomas. 1987. *Agronomic evaluation of poultry manure as a nitrogen source for conventional and no-tillage corn.* Agron. J. 79: 563-570.
19. U.S. Department of Agriculture. 1980. *Report and recommendations on organic farming.* Washington, D.C.
20. U.S. Department of Agriculture. 1981. *The universal soil loss equation with factor values for North Carolina.* Soil Cons. Serv., Raleigh, N. Car.
21. U.S. House of Representatives. 1988. *Low-input farming systems: Benefits and barriers.* House Rpt. 100-1097. Washington, D.C.
22. Young, Douglas L., and Walter A. Goldstein. 1988. *How government farm programs discourage sustainable cropping systems.* Proc. of Farm. Syst. Res. Symp. 1987. Univ. Ark., Fayatteville. pp. 443-459. □

Henry Smith

Sustainability of dryland cropping in the Palouse: An historical view

By Michael D. Jennings, Baird C. Miller, David F. Bezdicek, and David Granatstein

ALTHOUGH technological advances and varietal improvements have nearly doubled grain yields since World War II, the land resource in the Palouse region of the Pacific Northwest has undergone significant deterioration over the past 100 years (*12, 21, 32, 33, 37*). This historical trend has sparked concern about the ability to sustain present crop production levels over the long term. Degradation of the land base has resulted from significant topsoil losses, changes in soil structure and chemistry, and reduced soil organic matter. These factors are the consequence of tillage methods, crop rotations, and fertility practices used during this century.

An historical perspective on the impacts of the cereal-based agricultural system on the land resource is useful in identifying changes that will help sustain the productivity of the region's soils. A look at historical data does not imply a return to preindustrial agriculture. Rather, it offers an opportunity to use previous research and innovation in which society has already invested. With limited resources to devote to solving current agricultural production problems, a blend of pertinent historical wisdom with emerging technology is needed. More than a century of agricultural research and field experience in the Palouse has provided insight to help address issues of sustainability for dryland farming.

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Eras of agricultural history

Four major historical eras of farming technology in the Palouse have been identified. These provide reference points for prioritizing future research, policy, and farm practices as agriculture moves into an era of resource conservation and land stewardship.

Sodbusting (1870-1910). The upland bunchgrass prairie, which made up most of the Palouse, was first planted to grain in the mid-1870s. By 1890 most of the region was in private ownership, and by 1895 a great deal of the tillable land had been plowed. At first, farms were often homesteads that practiced diverse subsistence and commercial agriculture, including livestock, fruit, and field crop production. Many farms, however, soon moved toward specialized, large-scale grain production, similar to what was occurring in California at the time (*15*).

After breaking the sod, crops of wheat, oats, and barley were planted with a minimum of tillage—horse-drawn single- or double-bottom moldboard plowing and harrowing. Fertilizers were not used, and grain/pasture rotations were practiced occasionally. Initially, summer fallowing was not widespread, but more frequent tillage soon became popular, with some farmers tilling a fallow field 6 to 10 times in a season (A. McGregor, personal communication, 1989).

The organic matter content of soil recently converted from native prairie to grain production was five to eight percent, depending on the landscape position (*29*). In the early 1900s the Rosalia Chamber of Commerce (*27*) reported per-acre yields as high as 38 bushels of wheat, 95 bushels of barley, ,and 130 bushels of oats after a good growing season.

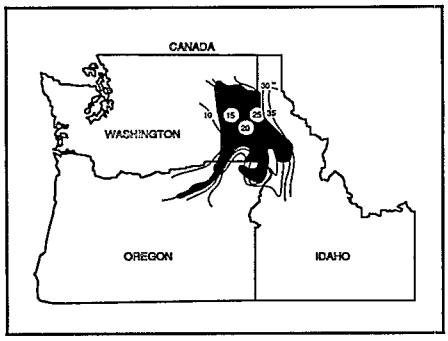
Soil erosion was not recorded as a significant problem, although Spillman of Washington State College began lecturing on its potential danger. Local flooding in Pullman and Colfax during this era did not produce significant amounts of sediment (*9*). Agri-

cultural literature of the time included reports on grain smuts and their prevention by seed treatment; discussion of the relationship between nitrogen and humus; and methods for growing alfalfa, grasses, clovers, and peas.

Liquidating the organic capital (1910 to mid-1930s). During the second and third decades of the 20th century, three major changes in farming practices altered Palouse soil conditions: summer fallowing, widespread cropping of dry peas, and stubble burning. These changes resulted in severe soil erosion and a depletion of soil organic matter. Kaiser (*9*) reorted that the most severe, sustained annual soil loss by water erosion in the Palouse occurred during this era.

Tillage-intensive summer fallowing became widely practiced during this period. In the drier areas soil moisture had to be stored one year in every two or three for a grain crop. By tilling the soil surface during the dry summer season, a dust mulch two to six inches deep was maintained over moist soil, preventing the moisture from reaching the surface, where it could evaporate. Also, by preventing any plants from growing in the soil, soil moisture loss by plant transpiration was eliminated. Because no alternative crop or management strategy compares economically with a wheat-summer fallow system, it remains a standard practice today, but is less tillage-intensive.

In annual cropping areas, however, summer fallow was discouraged by the agricultural experiment stations (*35*). It was used in these areas to control weeds and to build up nitrate-nitrogen for the subsequent grain crop. For many years, farmers received payments for regular tillage of summer fallow ground to keep weeds in check (A. McGregor, personal communication, 1989). Mineralization of nitrogen from organic matter resulted in nitrate accumulation under summer fallow conditions. Largely a microbial process, mineralization is enhanced by adequate soil moisture and elevated soil temperatures created by summer fallowing. The advent of herbicides and nitrogen fertilizers has reduced the need for summer fallow in the higher rainfall areas, but it is still used occasionally to satisfy government set-aside requirements.



Location and precipitation zones (inches per year) of the Palouse region.

Summer fallowing sets up a degrading, positive-feedback system of enhanced nitrogen mineralization, loss of soil organic matter, and increased soil erosion. Because crops are not grown every year, the amount of organic matter returned to the soil is reduced. The loss of organic matter resulting from tillage without added residue reduces the soil's ability to absorb precipitation, thereby increasing the potential surface water runoff. The increased surface water runoff erodes topsoil, which contains most of the organic material in the soil profile. Fall and winter precipitation following summer fallow in the annual cropping areas may not be fully absorbed when the soil moisture profile is not depleted by crops during the fallow season, thus contributing further to surface water runoff. Tillage methods used to maintain a finely pulverized summer fallow soil surface also reduce soil aggregate stability, further increasing the susceptibility of the soil to runoff and erosion.

Cultivation of field peas as a substitute for summer fallow in the higher rainfall zone of the Palouse became widespread by 1920. This resulted in a grain-legume annual cropping system. Pea cropping, however, also resulted in more intensive cultivation, burning of crop residue, and the appearance of many new annual weeds (*9*).

Prior to combine harvesting, grain crops were cut either with a horse-drawn binder or a header and hauled to stationary threshers. With the binder, the stubble was generally short, easily plowed under and worked into the soil. The header left long stubble that often was burned. Straw stacks left by threshing were used for livestock feed. By the 1920s, combines were widely used, but until 1933 there were no straw spreaders on combines. Straw was left in heavy windrows that could not be worked easily into the soil.

By 1933, 94 percent of the pea residue and 78 percent of the grain stubble was burned annually (*9*). Burning of crop residue caused a more rapid decline in soil organic matter than any other management practice (*7*). By 1922, the average organic matter content of soils in the Palouse had been reduced 35 percent (*29*), and by 1950 it had been reduced 47 percent (*10*) from the original levels.

Because of the compounding problems of soil erosion and the loss of organic matter, set in motion primarily by summer fallowing and crop residue burning, technological advances in the production system did not result in grain yield improvements. From 1900 to 1935 the winter wheat yield in the state of Washington averaged a nearly constant 23 bushels per acre (*24*). Pubols and Heisig observed, "Average yields were maintained largely by the use of improved methods of farming and by the introduction of superior varieties of wheat, even though the soil resources were deteriorating and precipitation was decreasing. The critical status of the soil resources and their rapid rate of decline suggest that effective soil and moisture conservation methods must be adopted in order to maintain yields as other countervailing forces may be inadequate" (*24*).

Early farming practices in the Palouse left short straw stubble that was easily incorporated back into the soil and straw stacks remaining after threshing were left for livestock use.

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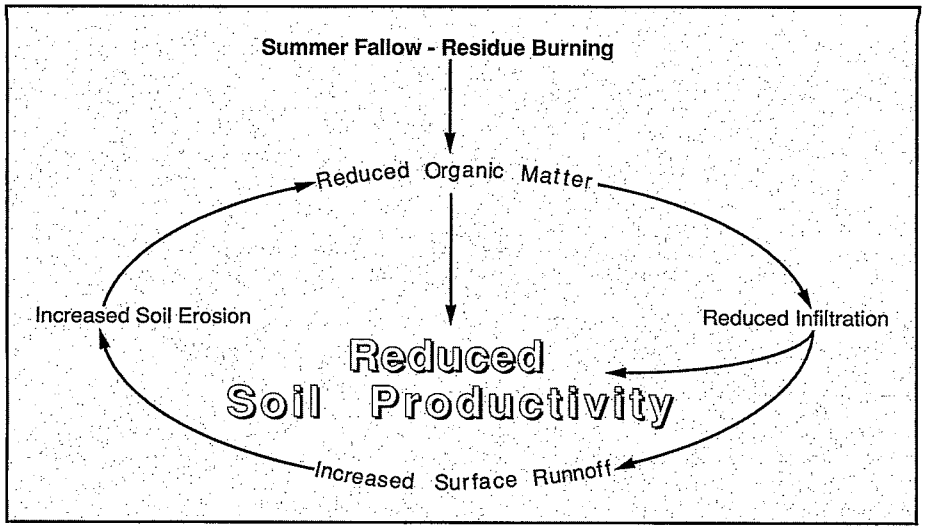
Power farming (mid-1930s to mid-1940s). Farming practices of the early 20th century were changed not only by technological advances but also by increased awareness of the problems of soil fertility and erosion. The most important change during this era was in the source of traction for tillage equipment, from horses to tractors. Other significant changes were in the management of crop residues, crop rotations, annual grain-pea recropping, and the decline of livestock operations.

By 1935, most farmers in the Palouse region had replaced horses with tractors. Tillage equipment pulled by tractors became larger and heavier. Rodweeders used to mulch the soil in summer fallowing were wider, disks were heavier, and plows increased from two bottoms to five or six. Most significantly, ground speed and the number of tillage operations were greatly increased, which increased the rate of tillage erosion (*9*).

Tillage erosion results when the mechanical action of tillage performed on slopes moves soil downslope. Almost all tillage gradually moves the topsoil down the slope (*16*). Busacca and associates (*2*) showed a downhill soil movement of 13 tons per acre from a single plowing on a six-degree slope in the Palouse, indicating that tillage erosion could be as significant as erosion from water. Kaiser (*9*) estimated that, by the end of this era, all of the topsoil was lost from about 10 percent of the farmland, and 25 to 75 percent of the topsoil was eroded from an additional 60 percent of the Palouse region.

In response to the problems of soil erosion and soil fertility, a number of important changes in farming practices were fostered by the U.S. Department of Agriculture's Soil Conservation Service in cooperation with Washington State University, the University of Idaho, and Oregon State University. Long-term research on soil conservation began in 1930 at the Soil and Water Conservation Experiment Station near Pullman, Washington. By the late 1930s, results from this work were applied to some Palouse farms. The following practices were included: within-field drainages were planted to permanent grasses; hilltop windbreaks were planted; straw spreaders installed on combines eliminated the heavy straw windrows, which improved crop residue incorporation and reduced the need for burning; grass-alfalfa pastures were included in crop rotations with grains and peas.

Even though these practices did slow the rate of soil degradation, they were not universally adopted. Summer fallowing and crop residue burning continued. Erosion control efforts suffered a severe setback during World War II, when grain production was accelerated under the Food for Freedom program (*32*). During this time, crop rotations that included perennial grass-legume pasture or green manure crops were abandoned for more intensive wheat recropping and wheat-pea rotations.



Degrading positive-feedback causes of reduced soil productivity.

Agrichemical and technological age (late 1940s to 1980s). The most dramatic changes in agricultural practices have taken place since World War II. Crop production output increased by extensive use of manufactured inputs. Average grain yields in the Palouse almost doubled during this period because of the development of high yielding, semi-dwarf wheat varieties, synthetic nitrogen fertilizer technology, a wide array of pesticides, and improved field equipment. In addition, government programs to subsidize prices for wheat and barley and to support research and development of new agricultural technologies have greatly influenced farming practices in the Palouse.

By the end of the Korean War, more than half of the farmers in the Palouse included grass-legume crops in rotation with grain and peas (*28*). At that same time, the principal nitrogen source for crops was shifting from dependence on soil organic matter mineralization and fixation by legumes to the application of synthetic nitrogen fertilizers. Nitrogen fertilization dramatically increased yields and helped to maintain soil organic matter levels (*23*) when compared with unfertilized cash grain rotations. Complex soil-building rotations were abandoned in favor of the more profitable, fertilized cash grain rotations. Yet nitrogen fertilizer did not fully substitute for the benefits of these long-term rotations, such as weed control and improved soil structure (*11*). Verle Kaiser, an influential soil conservationist (*9*), regarded commercial fertilizer as a good supplement to a sound grass-legume crop rotation that was needed to conserve the soil.

The use of synthetic fertilizers also assisted in residue management. Prior to the advent of synthetic nitrogen fertilizers, not only was crop production limited by nitrogen availability but the breakdown of crop residue often was limited by nitrogen availability, which led to yield reductions. Fertilizers made it feasible to incorporate straw into the upper soil surface, providing better erosion control and maintenance of the soil organic matter, instead of burning residue or burying it with a moldboard plow. This gave rise to tillage practices known as "stubble-mulching," "conservation tillage," "minimum-tillage," and "trashy farming."

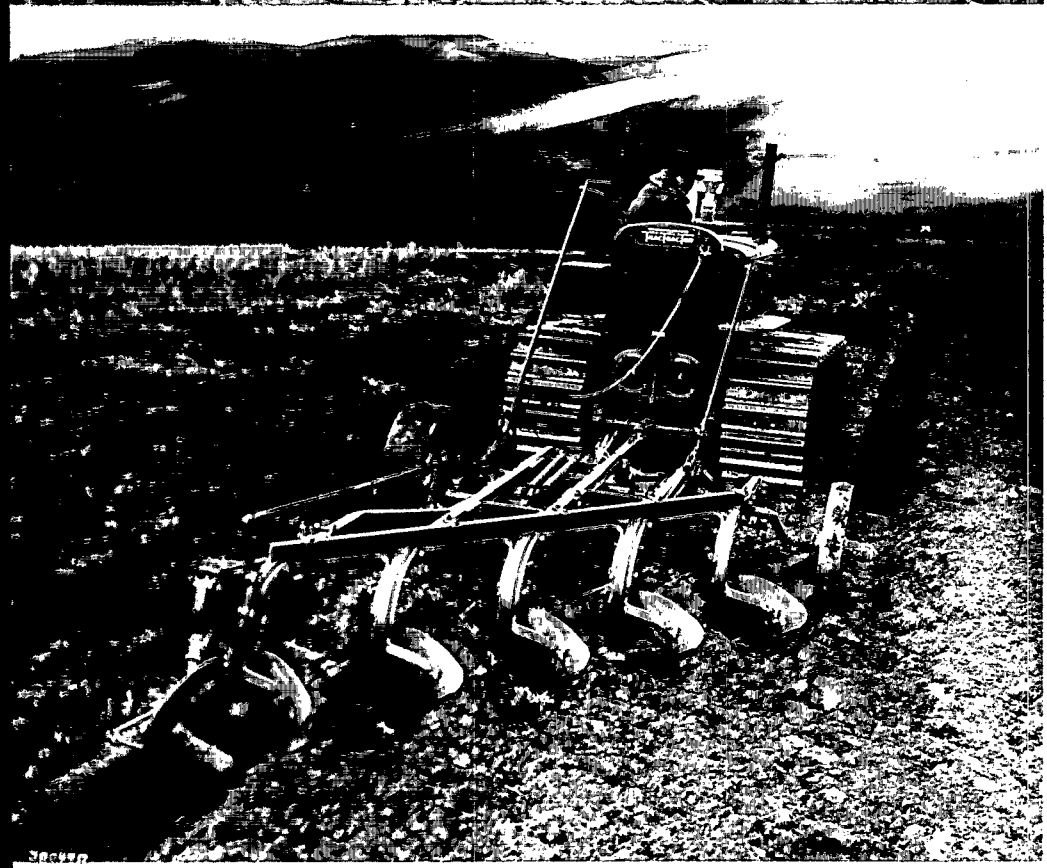
Extensive use of ammonium-based nitrogen fertilizer has been linked to direct and indirect alteration of soil characteristics. Soil pH of virgin soils in the Palouse region were near neutral, ranging from 6.6 to 7.4. By 1980, the surface soils of 65 percent of several counties in the higher rainfall, more productive areas of eastern Washington and northern Idaho had a pH of less than 6.0 (*14*). This soil acidification in the Palouse region has been attributed largely to the nitrification of ammonium-based nitrogen fertilizers, not to acid rainfall or crop removal of nutrients. Nitrification, however, is acid-producing whether the source is fertilizer or legumes.

Soil acidity can reduce microbial activity, the availability of some nutrients, and the productivity of many legumes often used to diversify rotations and fix nitrogen. Soil acidification also causes an increase in the water-soluble silica in the plow layer (*6*). Douglas and associates (*6*) speculated that this reaction could provide silica for cementation, a potential factor in hardpan formation. The significant role of heavy farm

machinery in soil compaction, however, must also be recognized. Although soil acidification can be corrected with lime applications, the Palouse region shows little evidence of crop yield response and economic benefit to this practice.

Researchers have established that anhydrous ammonia, a widely used nitrogen source, increases the water-soluble organic carbon in soils under experimental conditions (*18, 20, 31*). This water-soluble organic carbon subsequently is transformed by the microbial processes of assimilation and dissimilaation to biomass-carbon and carbon dioxide, respectively (*19*). Myers and Thien (*17*) showed a synergistic effect between ammonium and phosphorous fertilizer compounds of increasing soil organic matter solubility. Yet nitrogen fertilizers contribute significantly to soil organic matter through the addition of crop residue. The long-term net impact of nitrogen fertilizers on overall soil condition has not been clearly documented. In addition, the productivity and profitability of dryland cereal cropping currently relies on regular fertilizer use.

Soil erosion in the Palouse, such as this severe snowbank erosion near Oaksdale, Washington, resulted from the advent of power farming, exemplified by this circa 1938 photo (below) of a farmer plowing fields after residue burning.



Soil productivity for wheat in the Palouse is directly related to topsoil depth and topsoil organic matter content (*23*). The topsoil depth and soil organic matter in turn influence the soil moisture available for crop production. Several studies (*12, 21, 33*) have predicted what wheat yields would have been if erosion had been controlled and how continued erosion could affect future yields. The conclusion is that technological advances and varietal improvements during this period have masked soil productivity losses resulting from agriculturally related soil degradation.

Unless soil degradation is halted or technological advances continue to provide yield increases, soil productivity and crop yields will decline as topsoil becomes thinner, and the cost of production will increase. Soil degradation also increases the need for external production inputs, most of which rely on nonrenewable fossil resources.

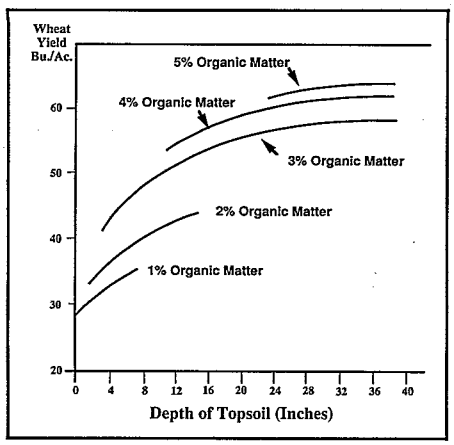
The choice of crop management systems can influence soil characteristics in the long term. In a recent study, soil properties on a Palouse farm using typical methods of crop production (Farm A) were compared with those on an adjacent farm (Farm B) that used longer crop rotations, green manure crops, and grass (*1, 22, 25, 26*). Farm A was first plowed in 1908 and Farm B in 1909. Farm A began using commercial fertilizers in 1948 and pesticides in the early 1950s. Farm B did not use synthetic fertilizer but did apply pesticides to a limited extent starting in the mid-1960s. Soil from Farm B, compared to Farm A, had higher organic matter, cation exchange capacity, total nitrogen, extractable potassium, water content, pH, polysaccharide content, enzyme levels, and microbial biomass. The soil from Farm B also had better tilth (lower modulus of rupture, more granular structure, less hard and more friable consistency) and, perhaps most important, about six inches more topsoil.

The soil differences were mostly attributed to the different rotations and, to a lesser extent, slightly different tillage practices.

The Palouse was, and is, recognized as one of the most erodible landscapes in the United States (*30*). Annual soil erosion rates on some slopes are 90 to 200 tons per acre (200 to 450 tons per hectare), with an overall average erosion rate of 14 tons per acre (37 tons per hectare) (*32*), which is estimated to be three times a sustainable loss rate (*5*). The 1982 National Resources Inventory showed the Palouse to have the second highest rate of sheet and rill erosion among the nation's major land resource areas (*13*). Estimates of the tons of soil lost via erosion per ton of grain produced range from 7 to 8.7 (*8, 32*). The Palouse River has deposited more than 535,000 tons of agriculturally generated sediment annually into the lower Snake River and has been recognized as a point source of pollution (*32*). Its water quality was, and is, impaired by organic matter enrichment, loss of riparian vegetation, elevated temperatures, and suspended sediment (*32, 34*).

The extent and intensity of crop production in the Palouse has contributed to a significant reduction in native plant and animal habitat diversity. In one representative Palouse watershed, less than 10 percent of the surface area was left to support non-crop vegetation, consisting of places too steep or too wet to plow, roadsides, and rock outcrops (*8*). Existing natural areas were found to be degraded in terms of original ecosystem structure, function, and size. For example, the function of riparian wetlands in reducing stream sediment had been almost eliminated because of alterations of their structure and size. Natural areas were being affected by regular burning, isolation by adjacent plowing, and direct or indirect herbicide application. Few native plant species and no native plant communities remained. Invasion by exotic plant species also has significantly affected native plant communities.

Federal farm commodity programs have reduced farmers' flexibility in managing their soil resource base (*3*). These programs are designed to stabilize commodity prices and assure adequate farm incomes. Young and Goldstein (*36*) have argued that the commodity programs encourage intensive production of a few select crops by restricting program payments to certain crops and by making payments based on historical acreages and production levels. This has discouraged diversification and the use of beneficial, soil-conserving crop rotations and has increased production pressures on the cropped land, further jeopardizing the soil resource. In the Palouse, the programs have encouraged producers to set aside their least productive and often most erodible land. This set-aside acreage is frequently summer-fallowed, setting the stage for further degradation in soil productivity.



Relationship of topsoil depth and winter wheat yields at differing soil organic matter levels under annual cropping conditions (23).

Departures from sustainability

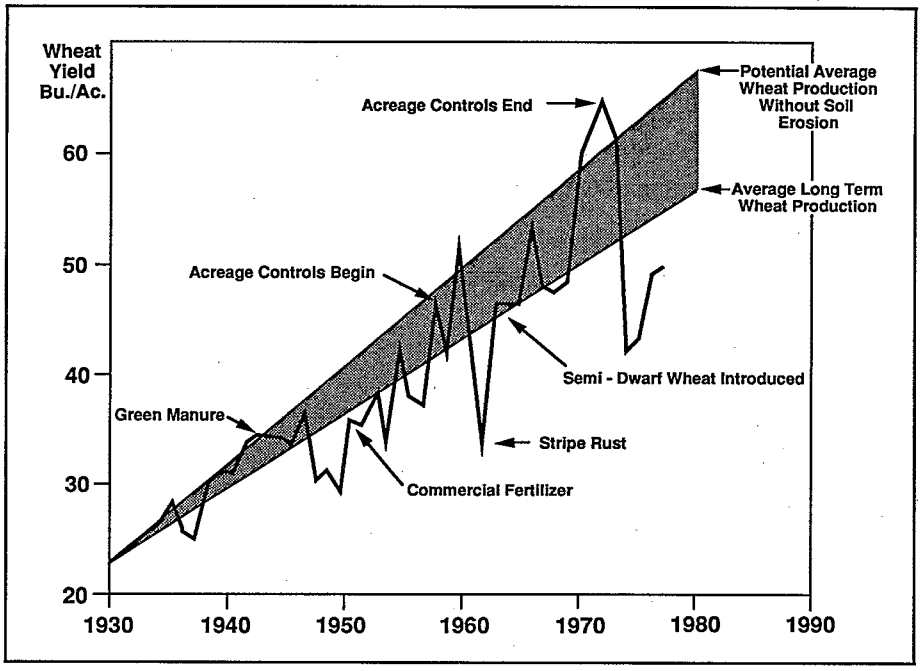
Farming practices in the Palouse grain-producing region over the last 100 years have not maintained the resource base. Continual degradation of soil productivity has been overshadowed by tremendous technological and varietal improvement, increased production inputs, and the extensive depth of the original loess soils. Some practices have been more detrimental to long-term soil productivity than others. These include tillage-intensive summer fallowing, the abandonment of complex soil-building crop rotations, the lack of widespread adoption of soil conservation practices, burning of crop residue, frequent tillage for "clean cultivation," and "downhill" moldboard plowing. Most of these practices have been used in the past because of their clear short-term economic benefit, government policies, or lack of suitable alternatives.

The future era

During the last 10 years, significant changes have begun to take place, signaling a new era of conservation farming. Adoption of conservation tillage systems, such as no-till, mulch-till, and reduced tillage for grain production, in Washington, Idaho, and Oregon has increased in recent years. In 1988, the cereal acreage on which conservation tillage methods were practiced was 34 percent, up from 24 percent in 1982 (*4*). This trend is expected to continue, particularly as the conservation provisions of the 1985 Food Security Act are implemented.

One of the major sources of new conservation farming technologies in the Pacific Northwest has been the multistate, interdisciplinary STEEP (Solutions to Environmental and Economic Problems) research program. More than 100 scientists from the land grant universities and the U.S. Department of Agriculture's Agricultural Research Service in Washington, Idaho, and Oregon have

Predicted winter wheat production loss from soil erosion in the Palouse River Basin (32).



participated in STEEP research efforts for the last 15 years. The program has focused on developing new technologies for more efficient farming systems that conserve soil and water resources.

During the last decade, an equipment technology revolution occurred, which facilitated the adoption of conservation practices. In the mid-1970s, growers had few planting and fertilizer equipment options for conservation tillage. Only six conservation tillage drills were available. Today, more than 60 models of conservation tillage drills are available commercially (R. Veseth, personal communication, 1990). Previously, fertilizers had to be surface-broadcast in no-till systems, which typically resulted in lower fertilizer use efficiency, limited yield potential, and increased infestation of grassy weeds. Now, more than 75 percent of these conservation tillage drills are designed to deep-band fertilizers for improved root access and reduced field operations.

Farmers are gradually shifting to conservation systems making use of tillage implements that leave more surface residue and a rougher soil surface, as well as reducing the number of tillage operations. The chisel plow is beginning to replace the moldboard plow, except when seed burial is necessary for difficult fall grassy weeds, such as downy brome. Major fertilizer dealers in the area are developing and promoting heavy-duty fertilizer applicators (injectors) for minimum tillage "shank-and-seed" systems. The applicators operate without prior tillage and eliminate the normal primary tillage operations. Farmers then seed with conventional drills after a herbicide application or preplant cultivation. The number of farms using divided slopes and contour stripcropping has also increased significantly.

The future holds many opportunities for improving the conservation of resources and providing better stewardship of the land. Policymakers are exploring ways to make government farm programs more flexible, which would allow for more diverse, soil-building crop rotations. Longer crop rotations can help to break pest cycles, reducing pesticide use. As a result of the conservation compliance guidelines of the 1985 Food Security Act, conservation practices will be applied on a wider scale.

The design of management systems will have to address water quality concerns. More efficient use of purchased inputs will be necessary to reduce the environmental and economic risks associated with farming. Farms could be divided into smaller management units, differentiated by landscape position, slope, aspect, and soil productivity, allowing for more site-specific fertilizer and herbicide recommendations. As an alternative to summer fallow, low-water-use, soil-building crops could be grown on set-aside acreage. Results of the biotechnology revolution will be integrated into pest control strategies on the farm. Farming will become even more information-intensive, requiring new methods to integrate and make use of new knowledge and technologies.

To maintain the highly productive farming systems in the Palouse, and in other agricultural areas, the perspectives and approaches used in designing farming systems must be broadened. By integrating the historical record, current knowledge, and future opportunities, the likelihood of sustaining the land resource and the agriculture it supports can be improved.

REFERENCES CITED

1. Bolton, H., L. F. Elliott, R. I. Papendick, and D. F. Bezdicek. 1985. *Soil microbial biomass and selected soil enzyme activities: Effects of fertilization and cropping practices.* Soil Biol. Biochem. 17: 297-302.
2. Busacca, A. J., D. K. McCool, R. I. Papendick, and D. L. Young. 1985. *Dynamic impacts of erosion processes on productivity of soils in the Palouse.* In *Erosion and Soil Productivity.* Am. Soc. Agr. Eng., St. Joseph, Mich. pp. 152-169.
3. Committee on Government Relations. 1988. *Low input farming systems: Benefits and barriers.* House Rpt. 100-1,097. U.S. House of Rep., Washington, D.C.
4. Conservation Technology Information Center. 1988. *1988 national survey conservation tillage practices.* West Lafayette, Ind. 144 pp.
5. Donaldson, N. C. 1980. *Soil survey of Whitman County, Washington.* Soil Cons. Serv., U.S. Dept. Agr., Washington, D.C. 141 pp.
6. Douglas, C. L., R. R. Allmaras, and N. C. Roager. 1984. *Silicic acid and oxidizable carbon movement in a Walla Walla silt loam as related to long-term management.* Soil Sci. Soc. Am. J. 48: 156-162.
7. Jaffri, M. Z. 1956. *Effects of farming systems on soil losses, organic matter changes, and trends in productivity of land in the Palouse wheat-pea area.* M.S. thesis. Wash. State Coll., Pullman. 138 pp.
8. Jennings, M. D., and J. P. Reganold. 1988. *Policy and reality of environmentally sensitive areas in Whitman County, Washington, USA.* Environ. Manag. 12: 369-380.
9. Kaiser, V. G. 1961. *Historical land use and erosion in the Palouse—A reappraisal.* Northwest Sci. 35: 139-153.
10. Kaiser, V. G. *Cultivation of soil in Palouse, Ritzville, and Walla Walla from 1880-1990.* Data from Verle Kaiser collection archives, Wash. State Univ. Libraries, Pullman.
11. Kent, R. L. 1957. *Conservation crop rotations in the Pacific Northwest.* J. Soil and Water Cons. 12: 269-272.
12. Krauss, H. A., and R. R. Allmaras. 1982. *Technology masks the effects of soil erosion on wheat yields—A case study in Whitman County, Washington.* In E. L. Schmidt and associates [eds.] *Determinants of Soil Loss Tolerance.* Am. Soc. Agron., Madison, Wisc. pp. 75-86.
13. Lee, L. K. 1984. *Land use and soil loss: A 1982 update.* J. Soil and Water Cons. 39: 226-228.
14. Mahler, R. L., A. R. Halvorson, and F. E. Koehler. 1985. *Long-term acidification of farmland in northern Idaho and eastern Washington.* Commun. Soil Sci. Plant Anal. 16: 83-95.
15. McGregor, A. 1982. *Counting sheep: From open range to agribusiness on the Columbia Plateau.* Univ. Wash. Press, Seattle. 482 pp.
16. Mech, S. J., and G. R. Free. 1942. *Movement of soils during tillage operations.* Agr. Eng. 23: 379-382.
17. Myers, R. G., and S. J. Thien. 1988. *Organic matter solubility and soil reaction in an ammonium and phospshorous application zone.* Soil Sci. Soc. Am. J. 52: 516-522.
18. Norman, R. J., L. T. Kurtz, and F. J. Stevenson. 1987. *Solubilization of soil organic matter by liquid anhydrous ammonia.* Soil Sci. Soc. Am. J. 51: 809-812.
19. Norman, R. J., J. T. Gilmour, and P. M. Gale. 1988. *Transformations of organic matter solubilized by anhydrous ammonia.* Soil Sci. Soc. Am. J. 52: 694-697.
20. Papendick, R. I., and J. F. Parr. 1966. *Retention of anhydrous ammonia by soil: III. Dispersing apparatus and resulting ammonia distribution.* Soil Sci. 102: 193-201.
21. Papendick, R. I., D. L. Young, D. K. McCool, and H. A. Krauss. 1985. *Regional effects of soil erosion on crop productivity—The Palouse area of the Pacific Northwest.* In R. F. Follett and B. A. Stewart [eds.] *Soil Erosion and Crop Productivity.* Am. Soc. Agron., Madison, Wisc. pp. 305-319.
22. Patten, A. G. 1982. *Comparison of nitrogen and phosphorus flows on an organic and conventional farm.* M.S. thesis. Wash. State Univ., Pullman. 108 pp.
23. Pawson, W. W., O. L. Brough, J. P. Swanson, and G. M. Horner. 1961. *Economics of cropping systems and soil conservation in the Palouse.* Tech. Bull. No. 2. Agr. Exp. Sta., Idaho, Oregon, and Washington, and Agr. Res. Serv., U.S. Dept. Agr., Washington, D.C. 124 pp.
24. Pubols, B. H., and C. P. Heisig. 1937. *Historical and geographic aspects of wheat yields in Washington.* Bull. 355. Wash. State Univ. Agr. Exp. Sta., Pullman. 25 pp.
25. Reganold, J. P., L. F. Elliott, and Y. L. Unger. 1987. *Long-term effects of organic and conventional farming on soil erosion.* Nature 330: 370-372.
26. Reganold, J. P. 1988. *Comparison of soil properties as influenced by organic and conventional farming systems.* Am. J. Alternative Agr. 3: 144-155.
27. Rosalia Chamber of Commerce. 1906. *On the battleground, Rosalia, Washington: Vol. I.* In N. W. Durham [ed.] *Spokane and the Inland Empire.* Clarke Publ. Co., Spokane, Wash. p. 630.
28. Schwendiman, J., and V. Kaiser. 1960. *Alfalfa to replace sweetclover for dryland green manure crop rotations in the Pacific Northwest.* J. Soil and Water Cons. 15: 257-263.
29. Sievers, F. J., and H. F. Holtz. 1922. *The silt loam soils of eastern Washington and their management.* Bull. 166. Wash. State Univ. Agr. Exp. Sta., Pullman. 61 pp.
30. Steiner, F. R. 1987. *The productive and erosive Palouse environment.* EB 1438. Coop. Ext., Wash. State Univ., Pullman. 42 pp.
31. Tomasiewicz, D. J., and J. L. Henry. 1985. *The effect of anhydrous ammonia applications on the solubility of soil organic carbon.* Canadian J. Soil Sci. 65: 737-747.
32. U.S. Department of Agriculture. 1978. *Palouse cooperative river basin study.* Washington, D.C. 182 pp.
33. Walker, D. J., and D. L. Young. 1982. *Technical progress in yields—No substitute for soil conservation.* Current Info. Series No. 671. Univ. Idaho Agr. Exp. Sta., Moscow. 5 pp.
34. Washington Department of Ecology. 1988. *Draft nonpoint source pollution assessment report.* Water Quality Program, Olympia, Wash. 119 pp.
35. Washington State College. 1915. *Bunt or stinking smut of wheat.* Bull. 126. Agr. Exp. Sta., Pullman, Wash. 24 pp.
36. Young, D. L., and W. A. Goldstein. 1988. *How government farm programs discourage sustainable cropping systems: A U.S. case study.* In *How Systems Work.* Univ. Ark., Fayetteville. pp. 443-459.
37. Young, D. L., D. B. Taylor, and R. I. Papendick. 1985. *Separating erosion and technology impacts on winter wheat yields in the Palouse: A statistical approach.* In *Erosion and Soil Productivity.* Am. Soc. Agr. Eng., St. Joseph, Mich. pp. 130-141. □

PERENNIAL GRAIN
New use for intermediate wheatgrass

By Peggy Wagoner

MOST agricultural crops and all grain crops grown currently are annuals. Given the proper conditions, these crops can produce spectacular yields and good profits. Annual crops, however, are not necessarily the best choice for all situations, especially on highly erodible or marginal land. Soil erosion and other environmental problems associated with annual crop production currently are managed with such practices as contouring, terracing, conservation tillage, wind erosion reduction methods (2), and land set-asides.

Although these practices may control soil erosion, they may be undesirable for other reasons. For example, conservation tillage tends to depend heavily on agricultural chemicals that may leach into groundwater supplies. Development of perennial grain crops could provide farmers with an alternative that reduces soil erosion and improves environmental aspects of crop production. The concept of producing grain from well-adapted, herbaceous perennials was first presented by Wes Jackson in his book *New Roots for Agriculture* (3). Grain production from perennial grasses could provide an important alternative use for land that cannot sustain annual crop production.

The advantages that perennial grains have over annuals include year-round soil protection as well as lower annual inputs of labor and materials. Mechanical field operations in a perennial grain system are reduced greatly because the soil is not worked each year, thus saving fuel and labor costs. Seed purchases and planting is done every 5 to 10 years instead of every year. Legumes planted with perennial grains reduce the need for commercial fertilizers.

A perennial grain/legume mixture can be compared to a grass/legume pasture, but the primary harvest product is grain from the perennial grass rather than hay. In some areas the value of perennial grain/legume fields can be increased by cutting hay or grazing the fields after yearly seed harvest. In addition, a perennial grain cropping system rebuilds soil structure by increasing organic matter, water infiltration, and biological activity in the soil. Because the soil has vegetative cover all year, wildlife, such as game birds and mammals, also might benefit.

Perennial grain research

Perennial grain research has been conducted at the Rodale Research Center in Pennsylvania since 1983. During the first several years, nearly 100 species of perennial grasses were tested for their potential as grain crops. Selection of the most promising species was based on these criteria:

- ► Vigorous perennial growth.
- ► Seeds with favorable flavor qualities.
- ► Easily threshed seeds.
- ► Manageable seed size (>0.2g/100 seeds).
- ► Synchronous seed maturity.
- ► Shatter resistance.
- ► Strong, nonlodging seed stalks.
- ► Seed heads held above foliage level.
- ► Dry-down of seed stalks at maturity.
- ► High potential for mechanical harvest.

Based on these criteria, intermediate wheatgrass, *Thinopyrum (Agropyron) intermedium,* was selected for its potential as a perennial grain crop. In the United States, this perennial relative of wheat is normally grown as forage and for erosion control in the Great Plains and intermountain West. Compared with other perennial grasses we tested, intermediate wheatgrass ranks high according to all of the selection criteria. It produces seeds that average 0.53 grams per 100 seeds (5); the seeds can be mechanically harvested and threshed using commercially available equipment; nutritionally, intermediate wheatgrass is similar to wheat, with slightly higher protein levels (1); the grain can be ground into flour for use in baked products; and it can be cooked as a whole grain, like rice.

At this stage in our research, we are focusing on two major areas of investigation: the evaluation of intermediate wheatgrass germplasm and development of cultural practices to produce intermediate wheatgrass grain.

Germplasm evaluation

Intermediate wheatgrass is a cool-season, rhizomatous grass native to the southern Soviet Union, central Asia, and eastern Mediterranean regions. To determine genetic variation within the species and to select the most promising types possible, we are evaluating germplasm samples from these areas of origin, as well as forage varieties developed in the United States.

Half of the Rodale Research Center's 250 accessions of intermediate wheatgrass were obtained from the U.S. Department of Agriculture's Plant Introduction Office in Pullman, Washington. As indicated by the office's passport information, these accessions were originally collected in the Soviet Union, Iran, Turkey, and other areas of the eastern Mediterranean region.

Additional samples have been received from germplasm banks outside the United States, including Plant Gene Resources of Canada in Ottawa, Ontario; the N.I. Vavilov Institute of Plant Industry in Leningrad; and the Institute of Crop Germplasm Resources, Chinese Academy of Agricultural Science, in Beijing. Nonselected germplasm as well as breeding lines have been obtained from U.S. and French researchers. Commercially available varieties of intermediate wheatgrass have been obtained from seed companies in the United States.

Evaluation of this germplasm began in 1988 (4). Characteristics being studied include seed yield and general growth habits. Each germplasm sample will be evaluated for these characteristics for at least four to six years to identify lines with the greatest potential for consistently high yields and favorable adaptability over a number of years.

Based on information collected in 1988, growth characteristics, such as plant height, date of maturity, and general vigor, did not vary greatly among accessions. Minor differences in disease susceptibility of the seed heads were noted, but there was much greater variability among seed yield characteristics. Large variations in seed weight, seed head fertility ratings, and percent threshability were found (4). These yield data were important for characterizing differences among accessions that otherwise look similar when growing in the field.

Of the 22 samples exhibiting highly favorable characteristics, 19 originated in the Soviet Union. The other three were U.S.

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selections. This indicates that the Soviet germplasm tends to be better adapted to our area than accessions from other locations (*7*). Efforts will be made to acquire more accessions of intermediate wheatgrass originating in the Soviet Union.

All accessions will be maintained in the research center's herbary for an another three to five years to further identify general growth characteristics and to determine if yield components change over time. Selection of germplasm to be used for breeding higher yielding, well-adapted varieties of intermediate wheatgrass grain will be possible only after a large number of accessions have been evaluated for a number of years.

The initial evaluation serves as a basis for future selection and cross-breeding of higher yielding, well-adapted lines for perennial grain production. Ultimate selection of promising lines will be based on agronomic characteristics and the grain's nutritional and food quality characteristics.

Development of cultural practices

Methods to produce intermediate wheatgrass grain must be developed to realize the potential of this perennial grain crop. Methods for large-scale production of seeds from intermediate wheatgrass forage varieties already have been developed by the seed industry in the western United States. For example, in Colorado and North Dakota, where several varieties of intermediate wheatgrass are grown commercially, seed production fields have been maintained for 5 to 25 years, and seed yields range from 50 to 400 pounds per acre per year (*6*).

Inputs for long-term production include nitrogen fertilizer, irrigation, herbicides, and, sometimes, cultivation between perennial grain rows. Information developed by perennial grass seed producers should be adapted to the production of perennial grains. It is important to develop environmentally sound and economically viable perennial grain production methods.

In 1984, we began testing methods of producing intermediate wheatgrass grain at the Rodale Research Center (*8*). We are interested primarily in developing techniques that maximize grain yields; maintain favorable soil fertility levels; and control weed, insect, and disease problems without the use of agricultural chemicals.

Plots of intermediate wheatgrass have been successfully established using a John Deere grain drill. Perennial legumes, such as white clover (*Trifolium repens*), have been established along with the wheatgrass to provide biologically fixed nitrogen in an effort to maintain the fertility of the system. Management techniques that have been tested in an effort to maintain the health and vigor of these wheatgrass stands for sustained seed production include:

- Thatch control by mowing, burning, and grazing.
- Fertility maintenance through the use of legume companion crops and manure.
- Weed control by mowing and rotary hoeing.

Soil and leaf tissue sampling began in 1986 to determine the flow of nutrients, particularly nitrogen, through the system and to determine how management techniques influence these nutrient levels. The use of manure and/or the presence of a legume companion, such as white clover or birdsfoot trefoil (*Lotus corniculatus*), increases the amount of nitrogen in leaf tissues.

Each August a small-grain combine is used to harvest grain from experimental plots. In addition, hand-harvested seed yield samples are taken prior to the mechanical harvest to determine yield potential of each plot. In 1988, 21 plots were harvested. Hand-harvested yields ranged from 36 to 371 pounds per acre of naked grain. Mechanically harvested yields ranged from 22 to 198 pounds per acre of naked grain, indicating that a substantial amount of seed is lost during mechanical harvesting. Newer equipment that can be better adjusted may reduce losses.

Grain yields in the past four years have ranged from 19 to 504 pounds per acre for hand-harvested samples and 8 to 279 pounds per acre for mechanically harvested samples (*8*). Although some of these seed yield results are lower than those obtained by seed producers in the western United States, our inputs are lower. We are not using any irrigation or herbicides, and our fertility is primarily from nitrogen-fixing legumes. Although yields are low compared to yields of annual grains such as wheat, it should be possible to develop economically viable perennial grain production methods. Reduced costs of inputs will make net profits possible at lower yield levels. In addition, perennial grains are being developed to grow on marginal land that cannot support annual crops.

A preliminary economic analysis of perennial grain production from intermediate wheatgrass was conducted by David Watt of North Dakota State University (*9*). Watt concluded that if yields of intermediate wheatgrass grain could be maintained at 500 pounds per acre for at least eight years, the break-even cost of the grain would be at or below six cents per pound. At this price, intermediate wheatgrass grain could penetrate existing markets. Such preliminary data provide direction for further research. Of course, all of this must be considered in the context of using and marketing this new grain crop.

Much more research is required to develop low-input techniques to sustain perennial grain productivity. Part of the answer lies in the development of appropriate management techniques. Another important consideration is the selection and development of productive, well-adapted germplasm.

The future

Development of perennial grain crops is a long-term prospect. It will require commitment and research from individuals involved in plant breeding, agronomy, grain utilization, and marketing. Interest in developing perennial grains is increasing. Members of the Food Quality Research Section of USDA's Western Regional Research Center are contributing to our knowledge of intermediate wheatgrass as a food grain. The staff of Carrington Research Extension Center in Carrington, North Dakota, has initiated agronomic and economic research on the use of intermediate wheatgrass grain. Evaluations of intermediate wheatgrass germplasm are being conducted by such researchers as Jurgen Schultz-Schaeffer of Montana State University and John Berdahl of the Northern Great Plains Research Center in Mandan, North Dakota.

Perennial grain cropping systems represent a whole new approach to grain production based on perennial rather than annual herbaceous plants. The benefits of this effort to the environment as well as to farmers are potentially great.

REFERENCES CITED

1. Becker, Robert, Grace Hanners, De Irving, and Robert Saunders. 1986. *Chemical composition and nutritional qualities of five potential perennial grains.* Food Sci. Tech. 19: 312-315.
2. Colacicco, Daniel, Tim Osborn, and Klaus Alt. 1989. *Economic damage from soil erosion.* J. Soil and Water Cons. 44(1): 35-39.
3. Jackson, Wes. 1980. *New roots for agriculture.* Friends of the Earth, San Francisco, Calif.
4. Schauer, Anne. 1989. *Evaluations of intermediate wheatgrass germplasm—1988 summary.* RRC/NC-8934. Rodale Press, Inc., Emmaus, Pa.
5. Schultz-Schaeffer, Jurgen, and Susan Haller. 1987. *Registration of "Montana-2" perennial* Agrotriticum intermedium *Khizhnyak.* Crop Sci. 27: 822-823.
6. Soil Conservation Service. 1985. *Annual technical report—1985. Bismarck plant materials center, part I.* Bismarck, N. Dak.
7. Wagoner, Peggy. 1989. *The study of intermediate wheatgrass as a perennial grain crop—1988 research summary.* RRC/NC-98/33. Rodale Press, Inc., Emmaus, Pa.
8. Wagoner, Peggy, and Anne Schauer. 1989. *Intermediate wheatgrass grain production trials at the Rodale Research Center, 1988: Summary.* RRC/NC-89/32. Rodale Press, Inc., Emmaus, Pa.
9. Watt, David. 1989. *Economic feasibility of a perennial grain: Intermediate wheatgrass.* In *Grass or Grain? Intermediate Wheatgrass in a Perennial Grain Cropping System for the Northern Great Plains.* Res. Rpt. No. 108. North Dakota State Univ./Rodale Res. Cent., Fargo, N. Dak./Emmaus, Pa. □

The Michigan Energy Conservation Program is helping farmers and forest producers conserve energy and natural resources

By Carey L. Draeger

Soil Conservation Service/Ken Meyer

Sustainable agriculture at work

SUSTAINABLE agriculture encompasses any farming system that minimizes inputs of nonrenewable resources. Its goal is long-term agricultural sustainability and profitability for the farmer. The Michigan Energy Conservation Program (MECP) is based on this definition as well.

MECP is designed to help farmers and forest producers conserve energy and protect the soil, groundwater and surface water, and other natural resources from unnecessary exposure and/or destruction due to agrichemicals. In MECP's second year, most participants realize the program's intense compatibility with sustainable agriculture: less reliance on energy-intensive practices, reduced use of pesticides and herbicides, increased education and knowledge of conservation methods for farmers, and most importantly, economic and environmental benefits for farmers.

MECP targeted six program areas for energy reduction: integrated pest management, fertilizer management, reduced tillage practices, irrigation scheduling and management, livestock management, and forestry management. In each area, participating agencies assist farmers in reducing energy inputs on their farms.

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Some background

MECP began nearly two years ago when Michigan's Legislature appropriated $16.5 million from two federal court settlements involving oil overcharges during the petroleum price controls of the 1970s. It began as a 30-month cooperative effort of five major agriculturally related agencies: the Michigan Department of Agriculture (MDA), local soil and water conservation districts, the U.S. Department of Agriculture's Soil Conservation Service (SCS), and the Michigan State University (MSU) Cooperative Extension Service and Agriculture Experiment Station. MECP's effectiveness relies on the shared participation of these organizations at both the county and state levels. Originally scheduled to end in September 1990, an additional $800,000 was added to the program's budget to continue it through December 1990.

To take full advantage of the strength of the cooperating agencies, a board of directors was created to encourage input and guidance by the directors of all participating agencies. Board members include MDA Director Robert Mitchell, SCS State Conservationist Homer Hilner, Michigan Association of Conservation Districts' President Josh Wunsch, MSU Cooperative Extension Interim Director Ray Gillespie, and MSU Agriculture Experiment Station Director Robert Gast.

Meeting on a quarterly basis, the board sets overall policy and direction for the program. For example, the board determined how direct grant funds would be allocated to districts and producer participants. The board also worked together to develop a consortium proposal for continued MECP funding to present to the Michigan legislature.

The MDA is the lead agency within MECP's structure. It oversees all funding to other participating agencies, maintains four regional assistant program coordinators who work with energy technicians and districts at the local level, employs a communications representative for public relations purposes, and reports to the U.S. Department of

Energy on use of MECP monies and achievements.

Each of Michigan's 83 soil and water conservation districts has at least one MECP energy technician, with a total of 89 technicians statewide. These individuals play a major role in the program by working directly with farmers and forest product producers to implement energy-saving practices. MSU's Agriculture Experiment Station creates and maintains demonstration plots to ensure effective energy-saving practices for the program. The Cooperative Extension Service provides informational/educational materials, conducts demonstrations and training sessions, and provides expert teams and district energy agents to assist in the transfer of information to technicians and MECP participants. SCS assists energy technicians in various technical areas associated with MECP and, in most cases, serves in a supervisory capacity for implementation of technical practices to the technicians at the district level.

MECP programs and practices

MECP has assisted more than 20,000 Michigan farmers and forest product producers in its 18-month existence. Through its energy-saving practices, more than $21.9 million in energy and agrichemicals have been saved. For every MECP dollar invested, more than two dollars in energy have been saved. For example, an Eaton County MECP-sponsored fertility program reduced input costs for 121 farmers by more than $130,000 last year. Taking advantage of phosphorus buildup in the soil from years of overapplication accounted for a majority of the savings. Other soil and water conservation districts used MECP funding to provide farmers with free soil tests to determine their nitrogen, phosphorus, and potassium needs. Seventy MECP technicians statewide reduced fertilizer inputs by more than 6,200 tons. Farmers have saved a total of $3,100,000 in unused fertilizer to date.

The intensive rotational grazing method fits in well with both MECP and sustainable agriculture. Directly related to fertilizer management, the system promotes input reduction and regrowth of idle land. Pastures are divided into small paddocks with movable fences; animals are moved on a one- to three-day schedule to provide rest periods for individual pastures. Dairy herds are moved every 12 to 24 hours, while beef and sheep may spend two to three days in each paddock. Labor and energy are saved as a result of having animals harvest their own food rather than cutting, raking, baling, moving, and storing baled forage.

More than 200 producers sought assistance from MECP's irrigation scheduling program last year to maintain yields while keeping irrigation costs in check. According to Ed Martin, MECP irrigation specialist, the irrigation scheduling program, offered by 15 soil and water conservation districts, provides growers with a weekly, tabulated balance of stored water in the soil profile. A computer program calculates daily soil water losses due to evapotranspiration and crop use at various growth stages and debits this from the amount of moisture available. The amount of water added to the soil from irrigation and rainfall is credited to the balance. This program allows growers to apply additional moisture at optimum times, making better use of the water applied. By following irrigation scheduling, growers never overfill the soil profile. This allows the soil to absorb typical summer rains without leaching agrichemicals to groundwater or having them run off to surface water sources.

MECP's integrated pest management (IPM) programs reduced pesticide applications by an estimated 1,500 tons last year. John Hayden, IPM program coordinator, says this system uses a variety of management strategies to keep pests below an economic threshold—the population at which the damage exceeds the cost of application. By using information from environmental monitoring and regular pest scouting, farmers can reduce pesticide expenses and applications, thus reducing production costs and maintaining profitable crop yields.

Groundwater quality and MECP

Another important aspect of both sustainable agriculture and MECP is the concern over nitrate contamination in water. MECP is operating a mobile nitrate test clinic van to help farmers apply only enough nitrogen to meet crop needs. Maurice Vitosh, the MSU/MECP fertility management leader, explains that farmers who test for nitrate-nitrogen may find that they can maintain yields and reduce nitrogen applications by taking advantage of nitrate-nitrogen currently in the soil profile. Applying the exact amount of nitrogen to meet crop yield goals reduces the amount of nitrate-nitrogen left in the soil after harvest that may leach into groundwater sources. Over 2,000 acres were tested by the mobile clinic, affecting more than 500 farmers.

Cover crops are being used by MECP as an excellent source of nitrogen for crops. Technicians are recommending hairy vetch, red clover, and other legumes for rotational crops to increase nitrogen fixation and reduce soil erosion.

Vitosh feels farmers are more willing to adapt new practices if they have the opportunity to see on-farm demonstrations and experience the resulting benefits of sustainable agriculture practices. On-farm testing programs answer the farmer's need to see and believe and offer evidence of increased profitability with minimum input.

Conservation tillage ups profit

Many soil and water conservation districts used MECP funds to purchase or lease 90 pieces of conservation tillage equipment for farmers to use free of charge. In some cases, acreage was limited to a specific number to allow equipment use by all interested farmers.

Conservation tillage prevents water and wind erosion, reduces runoff, decreases compaction, and increases retention of soil moisture. Results of the conservation tillage program include an increase in no-till corn by 13 percent, soybeans by 40 percent, small grains by 17 percent, and pasture and hay by 31 percent.

"Conservation tillage may cause an increase in use of some chemicals initially," says SCS's Hilner, "but this use is cut down once weeds are under control." Conservation tillage prevents excessive soil and water erosion and maintains good crop yields.

MECP farmers apply concepts

Dick Ekins comes from a conventional farming background. "My grandfather used to moldboard plow his fields, then use several different harrows to prepare the soil for planting," he says. "By the time he was done, the soil was so fine that much was lost to wind and water erosion." Ekins himself changed to minimum tillage practices on his 160-acre farm several years ago. He likes the idea of crop residue protecting his land from erosion and moisture loss. "I do the least amount of tillage I can and I still get good crops!" In 1986, his corn won the Jackson County No-Till Yield Contest with a 149-bushel per acre figure.

Ekins is an enthusiastic MECP participant. He feels the program came at just the right time: It helped him implement several practices involving IPM, animal waste management, and cover crops and increased his profits as well. For example, Ekins' use of herbicides on his corn crop has been reduced 30 to 40 percent with IPM practices. Instead of scheduled sprayings, Ekins reduces weed problems mechanically, cultivating once or twice a season. He also uses scouting practices and is more careful about actual herbicide applications, using a 12- to 14-inch band application. His choice of herbicides has become more selective, and he

stays away from restricted-use chemicals as much as possible.

Bob and JoAnn Fogg have been practicing sustainable agriculture on their 335-acre farm for several years. Ten years ago, the Foggs began questioning conventional farming practices and decided to make their farm more environmentally sound. They began on one field with reduced amounts of agrichemicals, studied the results, and gradually increased their acreage farmed in this fashion. Their fields are now insecticide- and herbicide-free.

"I don't have so much against commercial fertilizers per se," says Bob Fogg, "but I think we could greatly reduce the amount we use, try to use less-damaging types of fertilizers, and still make a profitable living from sustainable agriculture practices."

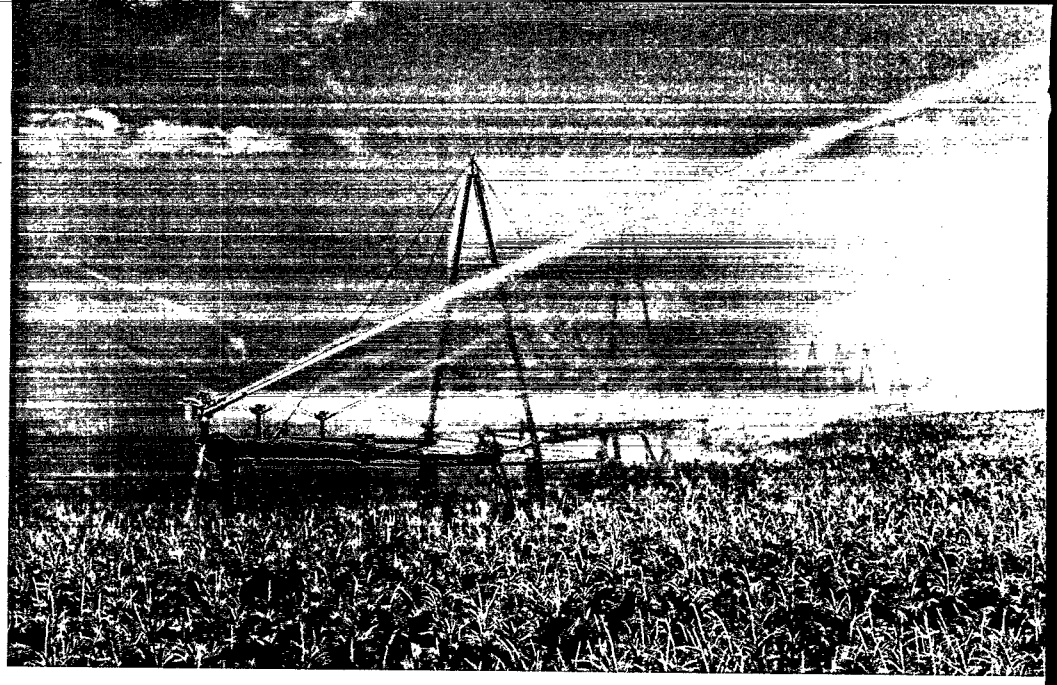
Over the last 9 or 10 years, the Foggs have gone from an outside-input system, which relies on nonrenewable resources, to a more sustainable system that relies on farm-produced resources with less risk of environmental damage. They follow a specific cropping program to maintain their soil's fertility: cover crops, green manure applications, and leaving a crop on a specific area. They raise a variety of crops to maintain their sustainable agriculture practices: corn, wheat, alfalfa, oats, hay, and other commodities. They also recently planted an acre-and-a-half of certified organic vegetables with the hope of achieving a farmer-to-consumer network for food purchases.

"It takes self-education and an open mind to change a person's attitude about sustainable agriculture," Fogg says. "It's not easy, but it works if you use good management practices. You've got to maintain the health of your soil and your crops."

MECP has been useful to the Foggs' farming practices. The program encouraged Bob to try no-chemical, no-till farming for corn and soybeans. Instead of chemical application, Fogg used a hairy vetch/rye seed mixture to combat weed pressure, killing the cover off by mechanical means. Fogg also tried intensive grazing with his cattle, using one-acre paddocks with a portable fence. The locations were changed every two days. One major benefit of the grazing program was encouraging vegetation on a formerly bare hill, reducing soil erosion in that spot.

MECP and cooperating agencies

Maintaining and preserving natural resources is a responsibility best shared by a number of agencies. MECP has demonstrated how quickly success can be achieved if it is shared through its multiagency characteristic. Each of the four participating agencies specializes in a particular area and shares this expertise with the other three.



Irrigation scheduling, computed for specific fields, has limited the leaching of agricultural chemicals in Michigan.

"Sustainable agriculture is not a new concept," says MSU's Gillespie. "Our agency has been recommending sustainable agricultural practices for years. The majority of our staff encourages good stewardship, and that's what sustainable agriculture and MECP are all about."

Sandra Yonker, MDA assistant deputy director agrees: "It's the wave of the future and it provides advantages to all sectors of the agricultural community. MECP has helped to form a coalition of agencies dedicated to working with farmers and other agribusinesses to achieve sustainable practices on a practical, profitable basis."

Yonker feels with MECP up and operating, more personnel are in the field where it counts the most to make sustainable agriculture a viable reality for farmers. An advisory committee on sustainable agriculture made up of state agency personnel, farmers, and other agricultural professionals has been created to continue promotion and education of sustainable agriculture. MECP provides a model to encourage increased adoption of sustainable agriculture practices by Michigan's farmers and forest product producers.

"MECP simply puts another column of soldiers out to help protect the environment," adds SCS's Hilner. "Our own financial resources were not enough for SCS to do the whole job. MECP is helping us a great deal to continue our practices of preserving the environment."

"In its first year of operation, MECP has proven to thousands of farmers that agrichemical inputs, such as pesticides and fertilizers, can be reduced without a negative impact on yields," says Ted Loudon, MSU/MECP project leader. "By balancing inputs to meet crop or pest control needs, producers reduce operation costs and decrease the amount of chemicals they put into the land."

Gordon Wenk, MDA project coordinator, adds, "The management of natural resources and farming practices for sustainability revolves around three critical areas: environmental protection, farm profitability, and social acceptance. In order for sustainable agriculture to become a reality, these three criteria must be met. We feel that the Michigan Energy Conservation Program does all of these things: it protects the environment through reduced and wise use of agrichemicals, it shows farmers how to decrease energy consumption and increase their profits, and farmers are enthusiastic about participating."

An ongoing success

The MECP is a successful multiagency approach that conserves energy and increases agriculture profitability while protecting the environment. It educates farmers and other agribusiness participants about natural resource conservation and offers practical methods by which sustainable agriculture can be maintained. Through local soil and water conservation districts, it offers a one-on-one delivery system of technical assistance and education to farmers and forest product producers, directed by locally elected citizens. At the broader statewide level, the MDA and MECP board of directors serve to enhance the local delivery of technical assistance and to locate future funding for the continuation of this most important program. □

Commodity programs and sustainable cash grain farming

By Bruce E. Lyman, Richard A. Levins, Michael A. Schmitt, and William F. Lazarus

REDWOOD County, in southwestern Minnesota, is primarily a cash grain-producing region. Corn is the predominant crop, with corn-soybeans the predominant rotation. Not surprisingly, the sign-up for government commodity programs is very high in Redwood County. Program payments have helped relieve the economic difficulties that plagued farmers throughout the 1980s. But looking to the coming decade, many farmers and farm leaders see economic issues making way for environmental issues as a major influence in agricultural decision-making.

Cash grain farmers in the area no doubt will be encouraged to adopt more sustainable farming practices. Two questions arise quite naturally from this. The first is simply, "What options do cash grain farmers have for becoming more sustainable?" The second concerns the incentives (or disincentives) that current commodity programs provide farmers who wish to become more sustainable.

After conducting a series of informal interviews with farmers in the county, we found that most cash grain farmers saw their options as being relatively limited. Furthermore, there was a consensus that straying from commodity program guidelines would be financially unwise, to say the least. One farmer talked of the "vise grip" in which programs held his farm planning process.

A case study we analyzed of a typical cash grain farm in the county supported what we learned from the interviews with farmers. If cash grain farmers are to adopt sustainable practices, significant changes will be necessary. Current commodity programs do not provide any incentives to adopt the sustainable practices we identified, and more than that, they penalize those who try them.

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Case farm description

The county extension agent described the farmer we chose to work with as typical of most cash grain farmers in the area. The farm was a single-family operation with 445 total crop acres. Corn, soybeans, and spring wheat were the principal crops.

The farm was in relatively sound financial condition. Two areas of concern were noted, however. One was that the bad times of the past decade had left little in the way of reserves for purchasing new equipment. The second was that the farmer's participation in corn and wheat programs was largely responsible for any profits shown. Without the program income, each dollar of farm output required $1.12 in farm expenses.

A detailed study of the cropping practices and soils on the farm led to three areas of concern that might motivate a move to more sustainable farming: (a) the timing and amounts of nitrogen being applied, (b) erosion control, and (c) the potential for leaching and surface runoff losses of herbicides.

Sustainable alternatives

We evaluated many alternative practices, such as applying nitrogen in the spring rather than fall and reducing chemical rates. The most sustainable alternatives, however, were ones that included a forage legume in the rotation system.

Alfalfa is the legume of choice in most of Minnesota. Alfalfa in the rotation system would address all three of the environmental concerns we identified for the farm. Nitrogen fertilizer requirements would be reduced, fewer herbicides would be applied, and soil erosion potential would decrease. We used a system in which alfalfa and oats were seeded together in the first year to reduce revenue losses during the establishment year.

One problem with producing alfalfa on this farm was that the farmer had no hay equipment and was not in a financial position to purchase any. We therefore budgeted the alfalfa harvest operation with custom charges rather than with equipment ownership and operating costs. The farmer also raised concerns about the market for hay. Although a few farmers can easily shift to hay without affecting the market, large numbers of farmers cannot. The macroeconomic effects of changing the grain/forage balance of our agricultural production system might well become a new concern for policymakers.

Six crop rotations

We evaluated six different crop rotations with respect to their profitability with and without the government commodity programs and their total nitrogen fertilizer herbicide requirements.

The first rotation is a baseline scenario with no major changes from the way the farm is currently being operated. Production is within the guidelines of the 1989 farm programs for wheat and feed grains, and the soybean substitution option is exercised at its 25 percent maximum. There is no reduction in crop base acreage for wheat or corn.

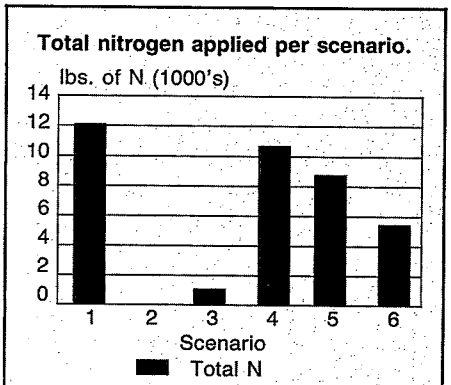
The second and third rotations reduce or eliminate base acreages and corresponding program payments. In the second scenario the available cropland is divided evenly among corn, first-year alfalfa, and second-year alfalfa. The wheat base is lost altogether, the corn base is reduced, and the relatively profitable soybean crop is no longer grown. The third scenario preserves wheat and divides the cropland evenly in a corn-soybean-wheat-alfalfa-alfalfa rotation. This system provides the environmental benefits and lower financial risk of growing a

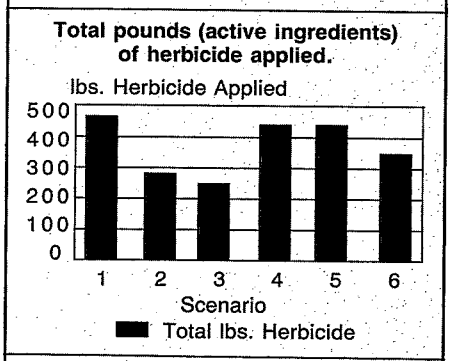
diverse crop mixture. It comes at a cost of losing the wheat base (acreage is exceeded), reducing the corn base, and growing fewer soybeans.

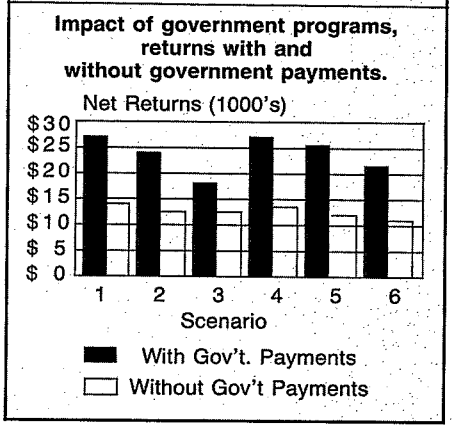
The last three rotations represent various ways the farmer could adopt more sustainable practices while staying within government program guidelines. All three attempt to follow a corn-soybean-wheat-alfalfa-alfalfa rotation without reducing the corn and/or wheat base. We will not describe each fully here because each turned out to be so operationally complex to implement that the farmer was in no way inclined to consider them. Planting would have to be done at levels of a few acres per crop in many cases, rather than the field-by-field strategies now in use. For example, scenario 6 would require corn to be grown after four different crops each year in acreages ranging from 2.5 to 66.3 acres. We show the results of these rotations only as a way of examining the wisdom of trying to satisfy environmental goals and commodity programs simultaneously.

Rotation scenarios evaluated, nitrogen saved, and revenue lost

Rotation Scenario	*Description*	*Nitrogen Savings (pounds)*	*Revenue Loss ($)*
1-Baseline system	Corn-soybean rotation with some wheat grown	0	0
2-3-way rotation	Corn-alfalfa-alfalfa	12,000	2,361
3-5-way rotation	Corn-soybean-wheat-alfalfa-alfalfa	10,660	7,144
4-In program	Half of wheat acres followed by alfalfa	1,539	645
5-In program	All wheat acres followed by alfalfa	3,078	1,480
6-In program	Maximum alfalfa within program guidelines	6,510	3,327







Results of analysis

The results of our analyses of the options available to this farmer are shown in the graphs, which depict total nitrogen fertilizer use and herbicide use and net returns with and without government programs.

Nitrogen fertilizer use was by far the highest with the baseline option, which was also the only practical way we identified to stay with program guidelines. If judged practical by the farmer, the base-preserving scenarios of the last three options would have significantly reduced total nitrogen fertilizer requirements. But all of the base-preserving options showed nitrogen fertilizer requirements well above those of options 2 and 3, the two options that were penalized because they reduced bases.

In Options 4, 5, and 2 require the farmer must give up the least amount of revenue to save a given amount of nitrogen below the baseline option. Options 6 and 3 sacrifice more revenue to save less nitrogen.

A common problem among all of the base-preserving options was that even when legumes were introduced, their nitrogen-fixing properties often were ignored as program considerations dominated agronomic considerations. For example, several scenarios forced the farmer to plant soybeans after a soybean crop—a situation both agronomically and environmentally unsound.

The herbicide use situation was similar to that for nitrogen fertilizer. None of the rotations eliminated the need for herbicides, but the two with the lowest requirements were also those that involved the biggest loss of government program benefits.

Net revenue resulting from reduced base acreages in the second and third rotations, compared to the baseline scenario, showed that adopting option 2 carried a $2,361 penalty and adopting option 3 carried a $7,144 penalty. The farm's financial picture would look much worse under either of the two best environmental scenarios.

Is the solution simply to eliminate government payments and make a "level playing field" for all? All of the options show reduced income if the current commodity programs are simply eliminated. No options we investigated would be economically sustainable at current farm costs and prices.

Conclusions

The farmer we worked with in Redwood County faces a dilemma common to many farmers in southwestern Minnesota. On the one hand, he is being encouraged to adopt more sustainable farming practices. On the other, government commodity programs discourage him from doing so.

What would help this farmer? One strategy would be to work to adopt more sustainable practices while staying within commodity program guidelines. But our work suggests that doing so results in cropping schemes that are impractically complex. Further, none of these schemes approaches the environmental benefits of those rotations that depart from program guidelines.

The best strategies are those that would result from more flexible base acreages. The vise grip of program guidelines must be relaxed; this much seems clear. But to simply remove all guidelines and payments is not practical. None of the options we investigated looked economically appealing when all payments were removed.

At the same time, incentives to produce in ways that are environmentally undesirable should be examined carefully. For example, the reward for pursuing option 1 instead of option 2 or 3 is much higher with the program than without. In place of such incentives, policies that encourage and support forages seem to make good sense for our case farmer.

REFERENCES CITED

1. Lyman, Bruce E. 1989. *Sustainable farming: An evaluation of selected options for a cash grain farm in southwest Minnesota.* M.S. thesis. Dept. Agr. and Applied Econ., Univ. Minn., St. Paul. 124 pp. □

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> *Leadership is not forcing other people to do what you want to be done, but empowering other people to accomplish what they want to accomplish*

COMMENTARY

Sustainable agriculture: Who will lead?

By Fee Busby

SUSTAINABLE agriculture is a dialogue—a discussion among people of many different backgrounds and interests, a search for both questions and answers. The result of the dialogue will be the development of a philosophy—a philosophy that describes the paradigm shift that I think we are experiencing.

Warren Bennis and Burt Nanus in *Leaders, the Strategies for Taking Change*, describe a paradigm shift as a "major turning point in history...where some new height of vision is sought, where some new fundamental redefinitions are required, where our table of values will have to be reviewed." Leadership in low-input and related agricultural issues requires that everyone contribute to this change by providing vision, redefinition, and value review.

Many of us participated in the industrialization and chemicalization of U.S. agriculture. The same people are now leading a new movement in agriculture—an agriculture that will use off-farm, purchased inputs more efficiently and effectively, minimize adverse impacts of the farming system on the environment and on the health of producers as well as consumers, and enhance farm profitability while sustaining the natural resources on which agriculture depends. A. T. Mosher, one of the leaders of the agricultural revolution in Asia, observed in 1966 that "agricultural development is as dependent on how effectively people work together as it is on the natural resources." This is just as true in the United States today.

The end of manifest destiny

I believe our current paradigm is an extension of this nation's manifest destiny philosophy, which was expressed in 1845 by Senator John C. Calhoun of South Carolina. This philosophy has been our rationalization for more than a century in believing such things as "man is dominant over nature," "big is better," and "economic efficiency is the bottom line." It was this philosophy that led to the mechanization and industrialization of agriculture; the taming of animals, land, and water to facilitate this industrialization; and the dependence on chemicals to squeeze the next increment of production from agricultural fields and pastures. It was this philosophy that led U.S. producers in 1972 to try and dominate world agricultural commodity markets by plowing fence-row to fence-row.

For more than 100 years the wisdom of manifest destiny has been questioned periodically. The establishment of Yellowstone National Park in 1872 and the national forest system in 1905 represented our nation's first answers to these questions. The soil conservation movement, which began in earnest in the 1930s in response to the Dust Bowl, was another answer. Since 1960, there have been more answers, including statements about the importance of multiple use of land and water, the need for wilderness preserves, and the necessity of evaluating human impacts on the environment.

Legislative actions to these ends resulted from citizens asking government to modify the manifest destiny philosophy. John Muir, Gifford Pinchot, Hugh Hammond Bennett, Aldo Leopold, Rachael Carson, and others spoke loudly and clearly about a better world. They laid the groundwork. The torch has passed. Leadership requires that we carry the torch and keep it burning.

The paradigm shift includes a vision that nature is dominant. The drought of 1988 taught us some very important lessons. Many people are concerned that we cannot answer questions absolutely about global warming and what effects such warming will have on the environment. Fortunately, the new paradigm includes humankind being comfortable in not knowing or thinking that we know everything. The new paradigm should include risk-management strategies, such as patience and unselfishness. With less-than-perfect knowledge, we must be willing to take our time. Humankind must live in harmony with nature, giving to nature as well as taking.

The new paradigm should lead to a recognition that small is beautiful and that diversity can contribute to environmental, economic, and cultural sustainability. The new paradigm should emphasize the effectiveness as well as the efficiency of policies and practices. One hundred years of policies and practices that have helped agriculture feed this nation and much of the rest of the world are judged efficient in most circles. However, because of the stresses and strains that have and continue to plague farmers, ranchers, rural areas, and the environment, it also is hard to judge the policies and practices as effective.

If agencies are to lead, they must have clearly defined, shared values that every single employee and client understands. The shared value that must be set for agricultural enterprises is sustainability. We must develop farming and ranching systems that maintain and enhance, through a proper mix of inputs, our soil, water, plant, and animal resources. This includes the cultural, social, and economic systems we have created.

Megatrends

I am far from the first who has suggested a major paradigm shift. John Naisbett, in his 1982 book *Megatrends*, described 10 changes occurring in our society. These changes and how I believe they relate to sustainable agriculture and leadership include the following:

► *From industrial society to information society.* This change is very true of sustainable agriculture because managing the complexities of agricultural systems that use crop rotations, animal manures, green manure crops, and integrated pest

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control practices for positive results requires more thought and information than does solving a problem with a plow or a chemical.

► *From forced technology to high-tech, high-touch.* This does not mean going backwards in time. Producers will not give up modern farming machines and chemicals. For instance, they will rely more on computer technology because computers offer the hope of dealing with the information that will be needed to farm successfully in the future. But mankind cannot mentally or emotionally survive when surrounded only by machines. Man needs to be touched both literally and figuratively by other living things—plants, animals, and other humans. Farmers need to get off their tractors and feel and smell the soil, handle the plants and animals, and be in harmony with nature. Consumers want products that they believe have been grown in harmony with nature.

► *From either/or to multiple options.* During most of the past 50 years, farm bills have included programs that tie farmers to certain crops through base acreage or other commodity program provisions. Farmers either followed the program or gave up significant government support options. The need to concentrate on certain crops resulted in farmers adopting certain production practices and management strategies. As more and more farmers chose to follow the program, more farmers farmed in the same way. The future will stress diversity on individual farms as well as in geographical areas. Farmers will have multiple options as to which crops to grow and how to grow them. Again, farmers will need access to information, including market information for numerous crops.

► *From national economy to world economy.* This transformation is certainly true in agriculture where food and fiber products are routinely traded on world markets. Agricultural technology and knowledge also moves from country to country. We are seeing a shift in the traditional direction of movement from developed countries to developing countries. For example, for several years we have seen small four-wheel-drive tractors that were designed for the small fields of Asia being introduced into the United States.

We are also seeing production practices being imported from developing countries to the United States and other developed countries. For instance, Asian farmers who have contributed so much to solve world hunger problems through the green revolution did so with fertilizers and pesticides. However, the costs of such inputs in Asian countries are high, and farmers were careful in what, how, and when they used such inputs. This is the essence of low- or proper-input agriculture. There is much that American farmers can learn from those who we usually think of as less developed.

► *From short-term to long-term.* Our planning, action, and evaluation strategies are changing from short-term to long-term. We will shift from making decisions because of short-term economic and political gains to being concerned about the long-term health of humans and the environment. I think sustainable agriculture is a long-term perspective to farming.

► *From hierarchies to networks.* The emphasis of the farmer-rancher research and demonstration programs included in the U.S. Department of Agriculture's low-input/sustainable agriculture (LISA) program is designed to network farmers to farmers and also farmers to researchers, educators, and technology transfer agents. This shift in organization should lead to new and improved strategies for farmers to organize themselves so they can better deal with issues affecting their farms and communities. We no longer look toward the hierarchies of research, extension, and technology transfer agencies to solve all of the problems. I believe that the future organization of agriculture will resemble a multidirectional, multirelationship web instead of a chain. An interesting question is how decentralized agencies will allow themselves to become and how much responsibility will individuals at the field level be given to interract with farmers so that all participants work in a self-help mode? Because low- or proper-input farming will result in more diversified enterprises as well as diversified crops, agency personnel will have to deal with each farm as a unique, individual enterprise.

► *From centralization to decentralization.* Individuals will become more responsible for decision-making as well as taking action. Our past approach to farm programs tended toward centralization. Decoupling and decentralization are highly related concepts. As farmers diversify enterprises, they will seek new partners to joint-venture a variety of farming activities, including sharing of knowledge and marketing. How will the agencies deal with field personnel who will have to adapt the "tech guide" to fit local conditions? How will the tech guides and extension publications be revised to include local knowledge?

► *From institutional help to self-help.* In agriculture this means a new era when farmers will work with one another to accomplish common goals. Research, education, and technical assistance agencies will become partners in terms of gaining knowledge from as well as giving knowledge to farmers. We will have to become life-long or continuous learners if we are to become more responsible for our own decisions and actions.

► *From representative democracy to participatory democracy.* The National Environmental Policy Act of 1970, which requires environmental impact assessment and allows citizens

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involvement in the process from review of draft environmental impact statements to active involvement in preparing the assessment to the right to legally appeal government agency actions, is an example of a shift toward participatory democracy.

► *From North to South.* The geographical shift indicated in the tenth megatrend has been described as a shift from the northern industrial Rust Belt to the southern Sun Belt. While this seems to be true, a more drastic trend seems to be abandonment of the heartland as people migrate to the coastal states. Both trends have left heartland cities fighting to maintain an economic and cultural base. Small towns have already been consolidated into larger communities. The result is fewer and fewer neighbors to add a quality of life to our rural communities and to pay taxes to maintain rural services and infrastructure. This trend does not bode well for rural America or agriculture, whether it goes by low-input, conventional, or some other name.

The challenge

Seldom have the tools and practices we use today been the result of one discovery. For instance, what one discovery led to the development of the tractor? Most advances are the result of someone combining many ideas, each contributed by someone else, into a new practice, product, or service. Solutions to problems faced by agriculture today will come about by combining ideas contributed by others. Who will lead in this effort?

► Individuals who have a diverse background of knowledge from many disciplines or who are able to productively work with people from many disciplines.

► Individuals who have the courage, freedom, and flexibility to experiment and test the new combination of ideas that they develop.

► Individuals who are able to focus on and develop solutions for specialized local problems but who understand the global implications of the problems and solutions.

► Individuals who are open to and encourage new ideas, but who also challenge ideas and insist that those who promote ideas are willing to discuss them and allow others to add to them.

Thus, the challenge is to develop and apply knowledge from a wide array of disciplines so that problems can be looked at from all angles and multiple solutions can be considered. This requires that people have the freedom to think and to act on their thoughts to solve local problems. The only way to improve the world's agricultural situation is by improving each and every farm—one at a time.

The challenge is to neither reject nor endorse each new idea that comes along. If an idea seems too good to be true, it probably is. Yet that idea may hold the key to something that will work. Consider each idea, compare it with your prior knowledge, test it, combine it with the ideas of others, and use it when and where appropriate to solve problems.

Leadership is not forcing other people to do what you want to be done, but empowering other people to accomplish what they want to accomplish. Sustainable agricultural programs are built around the idea that farmers and ranchers will be in control. That is how it should have been all the time. In the past, agencies and the policies passed by Congress may have played too powerful a role in the system. It is of little value to debate whether someone took responsibility from farmers or farmers gave up their responsibility. It is proper, however, to move forward and support farmers as they struggle to empower themselves to make decisions and be in more control of their lives and their farms. □

An open letter to the agricultural community on defining sustainability

By Rick Williams

AT this time we must carefully refine our definitions of agricultural sustainability and a host of related terms. The necessity stems from a generally imprecise conceptualization of what sustainability can possibly be. It also grows out of deficient consideration of appropriate time scales on which to judge this property of ecological permanence.

Any attempt to define the properties of complex systems, such as agricultural field, farm, market, or ecosystem, falls short of the reality of those things. Sustainability grows best from a fertile imagination and a well-planted education. Sustainability becomes adaptive as a human way of living, physically and spiritually. It cannot be defined only in measurable parameters.

Clarifying perspectives

In identifying limits to potential sustainability of agricultural systems, the most critical variables are not those definable in economic terms but rather those arising from ecological entities and relationships. I should note here the derivations of the words economy and ecology because these are the suppositions from which views of sustainability necessarily arise. *Economy* is formed from Greek roots, *oikos* and *nomos,* meaning "management of the household." *Ecology* is also a combination from the Greek, *oikos* and *logos,* denoting "rationale of the household." Thus, my proposed tenet is that sustainability is ecological; it derives from inherent properties of the "household," not from its "management."

This approach—to view sustainability as a property arising from homeostasis within the ecosystem—implies that human management is critical in allowing human use, without appreciable abuse, of the system in question. Good management requires intimate knowledge of the system's ecology and intuitive perception of when the system is "right." And it requires awareness of, and action on, the degree to which intervention is possible without creating substantial instability and disequilibrium in the system. Simply, management does not imply control.

To the degree we can accurately interpret archaeological and fossil evidence, we can say with little doubt that the most sustainable human systems were those of small groups of hunter-gatherers dispersed within the ecological resource. Those conditions, with a limited human population, may have been maintained for several hundred thousand years. The oldest agricultural systems may be, at the outside, several thousand years in existence. The difference in scale is obvious. With this tentative comparison, it is pertinent to ask several questions: Can agricultural systems be sustained for very long at all? What are the inherent limits to agricultural systems? What limited the far older hunting-gathering systems?

These concerns can be attributed to the human influence called management. The critical characteristics that make management inappropriate for sustainability are the specific states of mind of the managers. When people believe they control the system, their management is inappropriate. When people expect the system to produce an output without reasonably balanc-

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ing inputs, the management is unreasonable. When people think their actions in the system are inconsequential, management is faulty. When people try to dominate, rather than cooperate, the approach is unsustainable.

Obviously these statements suggest bias, and mine may be particularly extreme. But I am justified in setting my sights on at least a hundred thousand years more of human agricultural survival. Even that scale may appear limited if we are strongly optimistic. We should try to be hopeful. Such an attitude is in reality humbling, not egocentric, and it compels us to make difficult decisions with considerably greater ease. Life-sustaining decisions in truth they are.

Components of sustainable management

The agricultural community at local and global levels must review seriously the options for sustainability. It should be obvious that no one approach is applicable to all farming situations. Certain principles, however, can provide guidelines toward achieving sustainability. These broad concepts are developed here by discussing some components or classes of agricultural systems. These things are grouped by categories of how sustainable they are commonly perceived as being. The first category consists of components perceived as more sustainable and the second, those considered less sustainable.

Agricultural practices commonly thought to have greater potential sustainabilities have been classified in recent decades with such titles as low-input, organic, ecological, regenerative, and biological. A variety of distinctive and not-so-distinctive classes of practices have arisen or been reborn as practices called conventional have become apparently less and less sustainable. Probably, those alternative methods are more sustainable, but whether such sustainability is so as a matter of scale or as a matter of presupposition is an open question. Decades or centuries are the scales within which I see differences. Those differences are meaningful enough, providing useful direction at this point, but not final answers. Simply, no final answers are possible because sustainability is a relative phenomenon.

The qualities these supposedly more sustainable approaches to agricultural practice have in common are apparently the nature and level of production inputs. The nature of the inputs is distinguishable as natural (or with little processing prior to use). The level of inputs is seen as low, but in actuality it may not be. An organic farm actually may haul in more total inputs, on a tonnage basis, than a corresponding conventional farm. The qualitative differences of respective inputs may be a difference in the degree of processing and a difference in the final form of the input.

An organic farm may use rock phosphate, and a conventional farm may use calcium or diammonium phosphate. Both types of farms may result in the same level of depletion of the basic resource, minable phosphates. Both types may alter the preexisting ecosystem to equivalent degrees. Valid and complete assessments are difficult to make. The organic farm probably increases the total phosphate pool, just as the conventional farm may do. Both alter the biological community compared to the earlier, unmanaged ecosystem. These comparisons suggest that we must question what criteria are most suitable to judge sustainability.

Conventional practices have been lumped as largely less sustainable. These practices include the introduction of synthetic pesticides, the application of processed fertilizers, and the use of machine tillage. The last practice has been shared by approaches considered more and less sustainable; this overlap clouds the issue. The degrees to which the first two practices are less sustainable have not been determined finally. These decisions will never be made absolutely because economics and politics have decided their fates in advance of ecological determinations. Of course, the ecological repercussions of those practices are also of considerable concern. As such, their sustainabilities have been presupposed, perhaps justifiably, perhaps not, when we compare them to the full range of practices that are presumptively considered more sustainable.

I purposefully make these arguments in an unclear manner—to illustrate metaphorically the degree to which these points have been glossed over by scientific circles and by the various expository media. The long-term scale has not been considered adequately, in my opinion. The sustainabilities of all these approaches may pale in the arena of millenia. Most participants and observers have not addressed whether we should question the various styles of agriculture in that context. In my view, practices should be compared definitely on that level of scale, if we are to be confident in our assessments, because that is the very level of ecological spans.

Ecological constraints are the ultimate determinants of sustainability. These restraints act primarily in two forms: in limitations to physical resource flows and in alterations to community gene pools. In constructing agricultural systems, humans have affected both the flows of resources and the compositions of gene pools. These changes were apparently necessary and deliberate or accidental, but there are few assurances (except the passage of time) that any or all of them are sustainable. Sustainability itself must be defined in terms of time scale first, and then the whole range of agricultural practices must be correlated to specific limiting factors and to the significant interactions among those factors. This is most certainly a daunting task. It may be easier to establish some forms of relative sustainability by trial-and-error efforts and educated, intuitive approximations.

Integrating sustainability

The previous statements can be summarized as four principles of agroecosystem management, the first pair covering physical resource management, the second two concerning genetic resource management:

1. Yield expectations and product removals from the agroecosystem should be kept conservative and moderate.
2. Intended and unintended inputs to the agroecosystem should be restricted, and losses other than product removals should be minimized.
3. All genetic additions and removals should maintain or enhance community structure and function within the agroecosystem.
4. Any alterations in genetic composition of the community should maintain or enhance the diversity of the agroecosystem.

These principles are conceivably consistent with the millenial scale proposed as ecologically appropriate for comparing sustainabilities. They are not bound by economic restrictions and so are less complicated by social and political influences. I do not pretend that the aspects involved in fair distribution of a healthful diet to the earth's people are not crucial to sustainability. But I do suggest that this goal may be better handled by concerning ourselves first with creating conservative ecological management by a conscious, capable human population. Of course, efforts on all fronts have to be integrated for even marginal effectiveness.

Science can help in these efforts by carefully identifying and

quantifying the limits to achieving long-term sustainability. Science, however, can by no means make final determinations because personal and moral judgments are required in human development, especially as we attempt to harmonize more creatively with the earthly song. Science is limited by observability and measurement. Sustainability, however, requires some efforts toward tapping a higher perception—intuition.

If I seem to speak confidently, it is from observation, reflection, and contemplation. By no means do I intend to say I know absolutely. What I intend to project is a sense of the mystery surrounding human existence and transcendence. Sustainability is the physical expression of wholehearted exploration of that mystery. The ancient hunter-gatherers and some early agriculturalists may have known this by virtue of the rituals they performed. Many of those rituals apparently focused on the human relationship to earth, water, sky, and heaven and to the multitude of living companions those people knew. Their purpose seems to have been to sacredly affirm those fellowships. Their effect may have been to ensure the long-term continuance of those ties. Science cannot replace those functions; it does not affirm sacredness.

There well may be modern examples of such spiritual intimacy with the earth and its creatures. These should be left intact and working. What the rest of us need, along with the knowledge wrought by science, is a knowledge of place and a belief in the sanctity of the earth and the multitudes of the living. The knowledge of place grows from direct experience of place and years of it. The belief in the sacredness of place grows from awareness of the wildness of place and of human existence from place. These cannot come from the efforts of science, though in practice the knowledge and belief of place may benefit from science.

Through this commentary, I am attempting to broaden the field and to expand the focus of human reflections on and actions toward sustainability. The most valuable element in achieving that permanence is diversity—diversity of involvement, of thought, and of action. Most certainly we must make every effort to maintain diversity of living forms. That diversity cradles and nurtures the environment necessary for the creative diversities of human living. I hope that is a living through many, many years and a living fully within our haven, the Earth.□

The flexibility of sustainable agriculture

By Wilson Scaling

WHILE probably no two people agree on a definition, "low-input, sustainable agriculture" generally refers to a wide range of farming styles and practices. It includes systems ranging from reduced chemical use to those labeled organic farming. The techniques used in a sustainable system may include crop rotations and other cultural practices that control pests, substitution of manure or green manure crops for synthetic fertilizers, careful nutrient management, and low-initial-cost conservation practices. And let's not overlook America's vast ranching industry on native range—the broad-scale, low-input agriculture and the original low-input agriculture in this country that involves no plowing, no planting, no intensive fertilization. The rationale for low-input agriculture is economic, environmental, and social. As concern for the environmental, and social. As concern for the environment increases, more and more producers are becoming interested.

We need to dispel two myths about low-input agriculture. First, some people have the mistaken impression that it means lower production and less profit. In fact, in some cases it can reduce costs and increase net profit. Instead of maximum production at any cost, the goal is to find the optimal production level, given production costs and the desire for sound resource conservation.

Perhaps the words "low input" are misleading. Instead, I like to use simply "sustainable agriculture" because it covers a wide choice of agricultural systems and because I want to dispel the second myth—that it will do away with agrichemicals.

While some people envision the elimination of agrichemicals, most understand sustainable agriculture to mean a rejection of the conventional wisdom, "If a little is good, a lot is better." The emphasis is on using the amount of agrichemicals truly needed to take care of pest and fertility problems without drastically reducing crop yields or livestock production; in other words, the wise and prudent use of agrichemicals—a goal that most of us can share, given today's production costs, thin profit margins, and concern for the environment.

Responsible and conservative use of pesticides and fertilizers just makes good sense to a farmer or rancher. It makes good sense because it reduces costs. It makes good sense because it protects the health of farmers, their families, their employees, and neighbors by protecting water quality and reducing exposure to chemicals.

Our good sense also tells us that the use of agrichemicals is important to the production of food and fiber in this country. Without fertilizers or pesticides, farmers and ranchers would be producing much less food at a higher cost. Without herbi-

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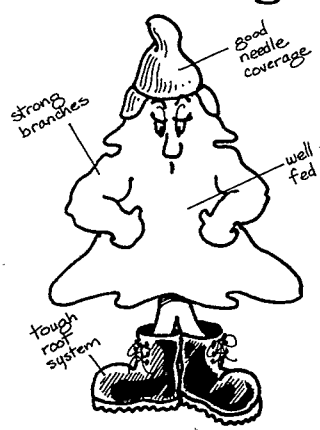

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cides, producers in the range country I come from would be less able to control brush, which crowds out grass and uses water that could replenish streams.

Thanks to the close cooperation of the research community and the agrichemical industry, we are learning a lot about the sensible, practical use and management of agrichemicals. Already technology is becoming incredibly precise. Agrichemical needs, for example, now can be measured in ounces per acre instead of pounds per acre. Pest scouting, band application of herbicides, and spot treatment of pest problems as they arise can all control costs and protect water quality. Agrichemical companies and other researchers continue to develop new chemicals with more targeted or shorter-duration effects. This is basically what we have known as integrated pest management (IPM). It is not something brand new. IPM has been used by progressive managers for many years.

Many of the practices recommended by the Soil Conservation Service (SCS) support sustainability; crop rotations, grazing rotations, plant selections, and waste management are but a few. SCS will continue to improve the technology available in the field, and we plan to work with the other U.S. Department of Agriculture agencies to help producers manage their total operation wisely. Our aim is to offer farmers and ranchers the widest possible choice of cost-effective and environmentally sound resource management systems with common sense, long-term profitability, and protection of America's resource base as the basic goals.

Pluses

I encourage those people in production agriculture to look at the possible advantages of sustainable agricultural systems. Here are just a few:

- Increased soil organic matter content, which improves soil microbiology and the soil's tilth and moisture-holding capacity.
- Increased crop diversity. This can reduce farmers' risks and benefit wildlife.
- Erosion reduction, thanks to the increased use of sod-based rotations or better crop residue management.
- Lower per-acre production costs, a benefit of more selective chemical usage. Manure can supply some or all of the nitrogen crops need. Crop rotations that include nitrogen-fixing legumes can play an important role in meeting the nitrogen requirements of a crop. Weeds can be controlled by crop rotation or mechanical cultivation, or both, and by careful management of herbicides. Biological agents might be an option for controlling weeds and insects.
- More efficient use of energy.
- Less chance of health risks associated with repeated exposure to chemicals.
- In some cases, the opportunity to take advantage of or to create special markets for fruits and vegetables.
- Better conservation of water, both quality and quantity.
- Improved habitat for a wide variety of animals, birds, and fish.

Minuses

Sustainable agriculture, however, is not a cure-all. So let's consider the other side of the equation as well:

- Some techniques can be more labor- and management-intensive. For example, pest scouting and more careful monitoring of soil fertility will require more time and more skill.
- There may be less time for earning off-farm income.
- In some cases, the farmer has to raise livestock or have access to livestock to make economical use of forage and to provide manure for nutrients.
- The switch to a longer crop rotation or changes in tillage practices may require additional investment in equipment and other operating costs.
- If large numbers of producers adopt the use of rotations with sod or legumes, there may or may not be markets readily available to sell the extra forage.

A way of thinking

These are practical considerations for any operation, and I encourage all farmers and ranchers to weigh their options.

The principles behind sustainable agriculture apply not just to farming. Americans in our cities and suburbs can draw on them as well, for prudent management of lawns, gardens, golf courses, nurseries, and road medians.

This practical kind of resource management that we call sustainable agriculture offers the flexibility that many American producers need to reduce farm costs, meet consumer demand, increase profits, and help the environment. It offers common-sense lessons and a way of thinking about soil and water conservation. □

Agriculture's role in protecting water quality

By Susan Offutt

AGRICULTURE is the remaining, major unregulated source of environmental, primarily water, pollutants. The nation's water resources include underground aquifers as well as lakes, rivers, and the oceans. As a significant nonpoint source of groundwater contamination, agriculture presents a thorny problem for the design of public measures to prevent pollution. Environmental policies tackled point-source pollution of surface waters first because cause-and-effect was easily observable; solutions were, therefore, easily found; and enforcement was possible. Groundwater problems, in contrast, are hard to detect and individual sources of pollution hard to identify.

The administration initiative

With the budget for fiscal year 1990, President Bush launched a federal government initiative to protect water resources from contamination by fertilizers and pesticides without jeopardizing the economic vitality of U.S. agriculture. Federal agencies will design water quality programs to accommodate both the immediate need to halt contamination, particularly of groundwater, and the future need to alter farming practices that may threaten the environment. The President explicitly made the point that farmers ultimately must be responsible for changing production practices to avoid contaminating groundwater and surface waters. Federal and state resources will be available, however, to provide information and technical assistance to farmers so that environmentally sensitive techniques can be implemented at minimal cost.

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The U.S. Department of Agriculture leads the initiative, in cooperation with the U.S. Environmental Protection Agency, the U.S. Geological Survey, and the National Oceanic and Atmospheric Administration. The President proposes that base funding of a quarter of a billion dollars be increased by about a third ($70 million) in 1990. Full, unearmarked funding of the initiative is critical, especially in this, its first year, as the administration envisions and has planned for a five-year program.

The President's plan embodies the belief that the most sensible approach to preventing water quality degradation for farming and for society is reliance on the farm community itself to devise and implement a pollution control program. Within this framework, research and education should develop and promote use of environmentally benign production practices. The very real threat of federal or state regulation should be a strong incentive for the agricultural community to embrace this strategy. This tact recognizes that federal regulation would be complicated by geographic variation in the physical environment that determines whether contamination actually does occur and with what severity. An effective regulatory solution, one that accommodates all sitespecific factors in prescribing best management practices, would be expensive to implement. An ineffective regulatory solution, on the other hand, could be wasteful in terms of inefficiency of resource use if use of chemicals and nutrients is proscribed unnecessarily.

The challenge to the efficacy of the envisioned voluntary approach is formidable, however. Research and development must design a set of best management practices that farmers will continue to use even if commodity prices rise significantly or input prices fall. Recent experience with adoption (and abandonment) of conservation tillage instructs caution in this respect. The lesson in designing and evaluating environmentally sensitive practices is to be mindful of the presence of coincidentally favorable price relationships. Over the past five to six years, low commodity prices have provided environmental benefits by reducing the incentive to apply pesticides and fertilizers to increase yields. Low output prices may in large measure explain the apparent success of "low-input" agriculture, although surely many farmers' attitudes have changed as well.

And it is difficult to be sanguine about the prospect of success today because basic production technology still depends upon fertilizers and chemicals. In the future, ensuring against surface water and groundwater contamination will require a truly alternative agriculture. Plants that fix their own nitrogen, repel insects, and outcompete weeds would obviate the need for man to help by applying nutrients and pest toxins. In this respect, advances in biotechnology could make very real contributions. The short-term question of coping with contamination persists, however, because society will not wait for science to deliver on this promise. Because groundwater contamination is very slow to dissipate and very difficult and expensive to ameliorate, there is no time to lose.

To both society at large and to farmers, a program of research and education aimed at water quality protection would have a number of advantages over compulsion through regulation. For farmers, education and voluntary compliance offer at least a partial cost-share through subsidization of the development of new farming practices and of the dissemination of information that aids in adoption. Maximum flexibility is provided to farmers when they may choose the practices that not only meet environmental objectives but also the needs of their own enterprises. And, importantly, voluntary programs are most in the spirit of farm policy over the past 50 years. For society, allowing farmers maximum flexibility also promotes efficiency in

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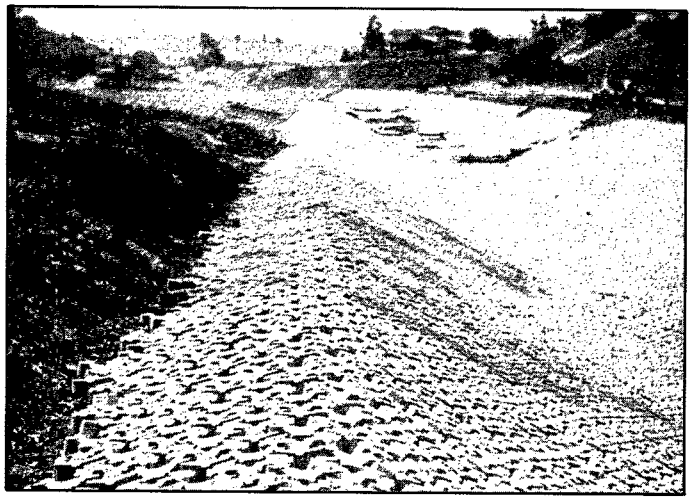

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resource use because the site-specific nature of groundwater contamination problems also dictates site-specific solutions.

Will it work?

The apparent mutual advantages of this framework notwithstanding, the real question is, will it work? Will it actually prevent groundwater contamination? And, will it work fast enough? It seems difficult to accept the argument that farmers will adopt environmentally sensitive practices in their own self interest. If this were the case, they would have done so long ago. Farmers may have alternatives to adoption of a pollution prevention strategy. They may draw drinking water not from individual wells but from municipal systems. As with urban areas, these rural municipal systems' treatment assures that the link between consumption and contamination is broken. Alternatively, a farm well may be moved to another, safer water source. Or it may be that farmers do not view the potential costs of their exposure to contaminated water as outweighing the benefits that chemical and nutrient use generate.

Beyond the not inconsiderable problems with sensitivity to commodity and input price changes, what barriers might there be to permanent adoption of environmentally sensitive practices? First, the question of diversification away from chemical-intensive crops, at least to allow for rotations, is critical. While diversification in cropping patterns currently is economically feasible in some areas of the country, it is not clear this is true everywhere. The economic forces, political and technological, that make specialization profitable need to be better understood and recognized in designing new multioutput systems.

Another barrier to groundwater quality protection may, ironically enough, be soil conservation. As was learned with conservation tillage, inhibiting runoff of chemicals and nutrients may lead to their percolation through the soil and perhaps into groundwater. What if acceptance of higher T values is the price of saving groundwater from contamination? How can institutional prejudice against such an outcome be overcome? Research can determine whether or not there is a tradeoff between surface water and groundwater quality. The more fundamental need is to recognize and accept that, no matter what, agriculture disturbs the natural environment. The issue is how much disturbance society is willing to accept, not whether it will accept any at all.

Regulation or voluntary action?

The President's water quality initiative puts its eggs in the research and education basket. But it is a choice that can be revoked. And pressure is increasing to do just that. The threat of regulation of farming practices is very real and must be given credence by the agricultural community. Society likely will not extend its long-standing exemption of farmers from responsibility for polluting. Making a case on behalf of farmers will be increasingly difficult as every other segment of the population has shouldered more and more of the cost of all kinds of pollution prevention and abatement. Many industries, such as basic metals, face the same stiff competition from overseas suppliers not necessarily subject to environmental regulation. As the President's initiative moves forward, the agricultural research and education community needs to be vigilant about monitoring progress and learning new lessons to promote farming's responsiveness to environmental concerns. Agriculture's unqualified support for the initiative's activities and goals would signal the minimum level of commitment necessary to forestall regulatory action.

For any other sector of the economy, the allocation of the financial burden for prevention of contamination is an easily settled matter: the polluter pays and is compelled to do so through regulation. Whether agriculture cannot only escape regulation, but also avoid the costs of pollution prevention, however, is problematic. In the absence of federal budget constraints, society could choose to provide farmers with a monetary incentive to avoid polluting. Indeed, cost-sharing programs have a long history in agricultural conservation policy. However, the scope of the effort needed to avert water quality problems, compounded by a shortage of federal funds, precludes extensive cost-sharing as a viable federal option. The bottom line is that farmers must recognize that there will indeed be costs to preventing water resource contamination and that it may well be their responsibility to accept those costs in moving quickly to meet society's demands for protection of environmental quality. □

Converting to pesticide-free farming: Coping with institutions

By Jim Bender

THE obstacles a producer faces in converting to pesticide-free farming are varied. I have come to appreciate that certain agronomic factors may be the greatest impediment to that conversion in many cases. Hence, some of these factors should be identified and discussed.

The federal farm program

The federal farm program that emerged from the 1985 Food Security Act provides an opportunity for, and an extraordinary obstacle to, conversion to pesticide-free farming. The obstacle is the notorious "use or lose" feature of crop subsidy program participation.[1] When a farmer plants less than his or her permitted acreage of program crops, a formula comes into play that can reduce permitted acreage—the basis for program benefits—in subsequent years. Acreage base for the next year equals one-fifth of the sum of acreage planted or considered planted over the last five years. A year of rotation to a non-program crop, such as clover, could result in the loss of up to 20 percent of a farm's base. It would be difficult to overstate the problem. Added to the challenges of adopting a new way of farming is that of reduced revenue from the federal farm program.

There are ways, however, to minimize the problem. As an example, I will use a farm in a soybean/corn rotation—typical in the Midwest—where the feed-grain base is 50 to 60 percent of total acres. The crop diversification and rotation required of pesticide-free farming entails that such a large feed-grain base cannot be preserved. Some of that base must eventually be sacrificed. The key is to delay the base reduction as long as

[1]The 1990 farm program has been amended to permit some substitution of non-program crops on base acres without loss of base. Because this change may be temporary, it remains useful to discuss strategies for coping with general program provisions that were obtained for many years.

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possible. One way is to commence with rotation and diversification by substituting from nonprogram crop acreage. Space for alfalfa could be derived from soybean acreage—which is not a program crop—rather than subtracting from the feed-grain base. That way, the feed-grain base is temporarily preserved.

Only after the nonprogram crop acres have been pared down as much as possible will feed-grain base acres have to be forfeited. This stage also can proceed as slowly as possible. Before giving up much of the feed-grain base, a farmer should allow time to be confident with new crops, rotations, and methods. This process could be spread out over many years if a farmer wishes.

The opportunity in the farm program for conversion to pesticide-free farming is found in the two set-aside programs. The yearly set-aside can be used to generally detoxify fields. More specifically, set-aside can be used to begin crop diversification and rotation, isolate and experiment with special weed problems, for example, bindweed, Canadian thistle, tan weed, hempdogbance, and begin to establish legumes and grasses. It also provides forage opportunities.

The Conservation Reserve Program extends opportunities to establish grasses and valuable trees. Beyond that, however, it could be used to partially stabilize income and workload for a conversion-minded farmer who is facing a variety of uncertainties. One way to make that conversion and also participate in the long-term set-aside is to commit just a portion of a farm to the program.

Lenders and farm managers

In discussing how to appeal to lenders, managers, and landowners, I will assume them to be somewhat rational (hence persuadable) and largely concerned with economic considerations. Lenders, managers, and farm owners who are also sensitive to environmental issues could have a wide array of considerations that will not be discussed here.

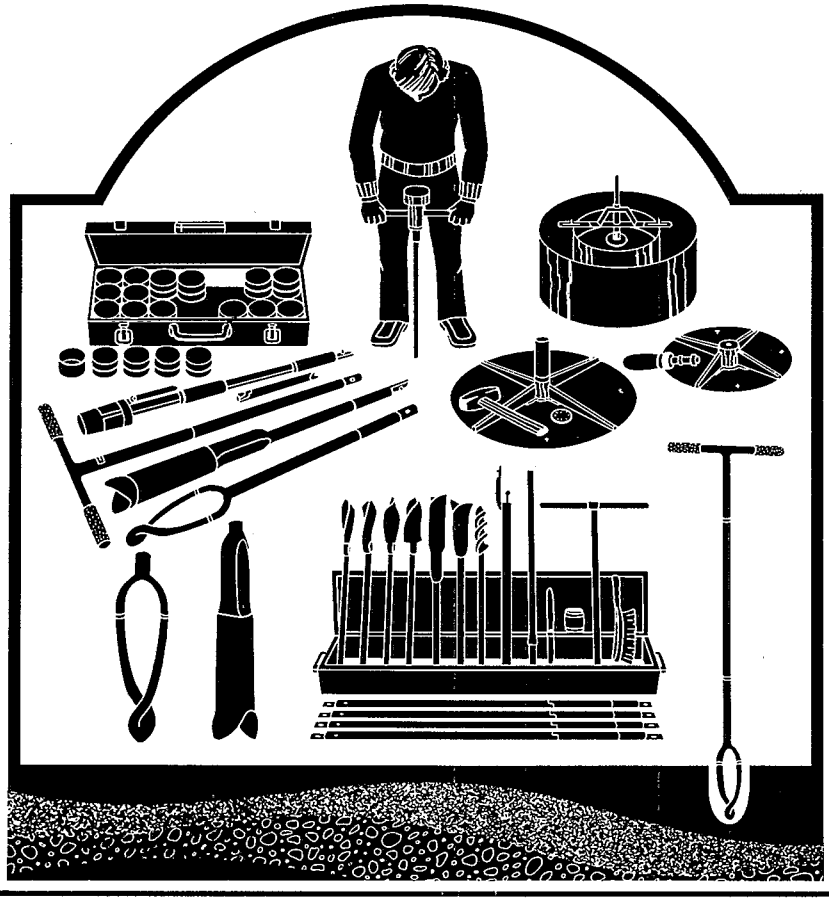
A subject to emphasize with a lender is the financial advantage of livestock. Livestock raising will almost surely be introduced, expanded, or merely more carefully organized as the farmer carries out the conversion process. At minimum, that offers the promise of greater financial stability.

Issues relevant to both lenders and managers are the prospects for reduced costs and enhanced financial stability through diversity. Cost reduction arises from gradually trading management for cash inputs and from methods that economically enhance soil resources, such as crop rotation, and use of legumes and grasses.

Lenders and farm managers are entitled to considerably more than the general discussions suggested above. To see why, consider what a conversion-minded farmer is proposing. From a lender's and manager's perspective, the proposed system is frought with uncertainties, and it gradually but permanently reduces government financial support. Even if these two changes can be made plausible, lenders and managers must decide whether the individual farmer who would be making the change is capable of doing so.

Accordingly, the farmer should prepare a written plan. This plan would describe in detail the goal, the conversion process, and a timetable. The timetable should provide for periodic review with all relevant parties. It should be to the farm roughly what long-term financial statements are to the farmer's financial picture and direction.

Given the magnitude of what is being asked of lenders and managers, a written plan constitutes minimum preparation. Sub-



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mitting a log of study also would be appropriate (including such items as the farmer's reading, seminars attended, and tours taken). Reading material also could be provided for the lender or manager, and model farms could be visited.

Farm owners

The relationship with the farm owner in the context of farm change is much more complex. There are two broad issues. The first involves persuading the farm owner. That seems to require a pattern similar to the process of convincing lenders and managers. The general issues are long-term productivity (from improved soil conservation, rotation, and livestock) and financial stability.[2] The written plan can be much the same as before, except with emphasis placed on farm changes rather than on the farmer's personal financial situation.

The second issue involves agreeing to terms that protect the tenant's situation. This issue arises for two reasons. First, conversion requires that acquisition of skills, work, and sacrifice come early, with the payoff emerging toward the end of the process. For example, in a typical conversion situation the tenant embarks on a long-term, soil-building program that includes detoxifying, adjusting acidity, applying manure, and organizing a crop rotation that includes legumes. The positive results, such as increased organic material, tilth, and water absorption, will be years away.

Second, part of the very meaning of conversion to pesticide-free or sustainable farming in general is that capital inputs (part of which the farm owner supplies) are replaced by labor and management (most or all of which the tenant provides). An obvious example is to trade chemical weed control for a strategy that includes careful rotation, adjusted and carefully planned planting dates, rotary hoeing, harrowing for cultivation, and shovel row-crop cultivation. Another example is to trade spraying of noxious perennials, such as bindweed, to provide temporary control for the nonchemical strategy of isolation and continuous tillage (which requires years) to provide for complete eradication.

Lease arrangements that do not address these matters place the tenant in an unacceptable situation. A minimally satisfactory lease in this context would have several components. It would be long-term, assuming that the tenant performs as agreed upon. It would stipulate the landowner's responsibilities for long-term investments, such as fences. It would provide for tenet compensation for adopting methods that partially replace landowners' costs. That provision can be expressed in adjusted crop shares, in cash rent, or with cash reimbursement.

Tenant farming entails serious obstacles for conversion to pesticide-free and sustainable farming. In general, if the landowner assents only reluctantly to trying sustainable techniques or if he or she will not be tolerant of experimentation and mistakes, conversion is not likely to succeed. Another option, although convoluted and distressingly time-consuming, would be to convert a separate farm unit not associated with the recalcitrant landowner, then use it as a demonstration farm to attempt to persuade that landowner. □

[2]Conventional farming, with its priority on corn and soybeans, imposes grain storage and handling pressures on many farms. These farms often have a cluster of buildings suited to the more diversified farming of earlier decades, rather than modern expensive storage and handling equipment. Tenants associated with such farms have an opportunity. They may point out to the farm owner that a diversified cropping plan is likely to reduce grain storage demands. Further, the old sheds, barns, and grainaries may be suited to alternative crops, such as hay and oats, as well as some of the tenant's livestock plans.

Wildlife and fish and sustainable agriculture

By Ann Y. Robinson

AN exciting dialogue has started across the country, as conservationists, organic food proponents, and average farmers find they have some concerns in common—concerns about groundwater, about health, and about net profits in agriculture.

The movement, if it can be called that, has been labelled low-input, sustainable, regenerative, or alternative agriculture. Whatever the name, the notion has been hailed by many as the best hope of reducing chemicals in water and food supplies and in the farmer's work environment. What is not so commonly recognized is the potential that this type of agriculture offers to improve the quality and quantity of habitat for fish and wildlife.

Conventional versus sustainable

To understand how a more sustainable way of farming could benefit wildlife, it helps to review the ways such a system differs from what has come to be known as "conventional." On modern, conventional farms the scale of fields and equipment is large. Usually, one or two crops are grown every year. Fewer of these farms have livestock, and if they do, animals are frequently confined in factory-like conditions that necessitate regular doses of antiobiotics to keep them healthy. Soil erosion levels are often high, as are the levels of pesticides applied to control weeds, insects, and diseases. Aerial application of chemicals has grown more common, exposing wider areas to drift. Fence rows, woods, and wetlands continue to disappear.

In contrast, the aim of sustainable farmers is to work with nature. They try to avoid many problems by maintaining healthy soil and plants and, when possible, to harness biological mechanisms like natural predators and seasonal rhythms that exploit pests' life cycles. Hands-on management and on-the-farm resources are valued over expensive off-farm inputs. Most advocates of sustainable agriculture are quick to point out that their goal is not necessarily to eliminate chemicals but to significantly reduce the need for them.

To achieve this reduction, farmers using these methods typically use selected rotations and cover crops to maintain soil "balance" and organic matter; substitute legumes, careful manure management, and biological controls for chemicals; and cut use of synthetic nitrogen to prevent possible disruption of soil biota and to save energy. Many such farmers practice ridge-till, a conservation tillage technique that requires minimal use of herbicides. There are other important features, aside from reducing chemical use, that tend to characterize this approach, including diversification of farm enterprises and an emphasis on buying locally, both which further the goal of sustaining communities as well as farms and natural resources.

Adherents of sustainable agriculture are more likely than their counterparts who practice conventional agriculture to voice respect for the nonhuman components of the rural landscape. They seem to recognize that wildlife helps gauge the general

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health of local ecosystems and enriches the countryside with beauty and economic opportunity.

The promise for wildlife

This type of thinking and farming holds real promise for wildlife and fish. For one thing, a greater diversity of crops and increased cover on fields could benefit a wide range of animals, particularly grassland birds. Because sedimentation from soil erosion is a number one threat to aquatic systems, an agriculture that takes better care of the land will be a boon to fish and anglers.

Pesticides can be damaging to fish, birds, and animals. While many insecticides are short-lived and relatively nontoxic to vertebrates at normal application rates, most are poisonous to aquatic invertebrates, a vital link in the aquatic food chain. Insecticides used on or near wetlands, particularly aerial applications, have been shown to reduce reproductive success for ducks and kill ducklings.

Weed killers are less of a threat to wildlife, but when they enter water supplies they have been shown to harm fish, particularly when more than one chemical is applied. Herbicides eliminate many of the plants that ducks feed on and that birds and fish use as cover. These chemicals also stunt and kill shelterbelt trees and other nontarget vegetation important as wildlife habitat.

Past conservation programs have operated primarily to patch up the undesired consequences of "regular" farm practices. Most have had limited success, which is understandable considering that they have generally worked against farm programs and tax and credit policies, which reward such practices as land clearing, farm expansion, drainage, and monocropping. The sodbuster, swampbuster, and conservation compliance provisions of the Food Security Act of 1985 removed some of these incentives for resource degradation. However, as is often the case with regulatory-type fixes, implementation has been stymied by politics and other constraints.

Prevention, not regulation, is the focus of regenerative agriculture. If the approach is to catch on, farm programs must be modified to support and reward landowners who use sustainable practices. A portion of farm program benefits should be redirected to encourage farmers to integrate alternative approaches into farming operations. Research and extension are essential to provide reliable information about what works in different situations.

Patrick Leahy (D-VT), Wyche Fowler (D-GA), and other senate agriculture committee members are working toward a consensus, sustainable agriculture and conservation package that includes many provisions from earlier versions of Fowler's proposed Farm Conservation and Water Protection Act. Senator Richard Lugar (R-IN) is sponsoring the administration's farm proposals that feature some compatible measures, such as protection of farm program base for those who want to diversify crops, and a version of the multi-year set-aside, supported by advocates of wildlife. Representative Jim Jontz (D-IN) has authored a bill that would modify commodity programs to encourage soil building rotations and provide assistance to farmers who implement a five-year "integrated farm management plan" designed to reduce chemical use and protect the environment. Other initiatives are expected as the 1990 Farm Bill develops, all attempting to eliminate some of the obstacles to stewardship, and move sustainable practices into the mainstream.

That is the challenge, to encourage mainstream producers to adopt ways of farming that are profitable, yet work more respectfully with nature to reduce reliance on chemicals and to protect soil, water, and wildlife. Some farmers have already embarked on this transition, some have been farming this way for years, and there are many others who want to try. Their efforts deserve support from hunters, anglers, and all who care about wildlife. □

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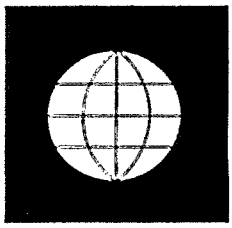

ACP cost-share practice developed

The Agricultural Stabilization and Conservation Service has developed a pilot cost-share practice that will allow Agricultural Conservation Program funds to promote more sustainable farming practices.

Integrated crop management (ICM) is designed to minimize pesticide and nutrient inputs while maintaining farm income. The cost-share practice, using many possible formats for chemical reduction, must produce a 20 percent reduction in chemical applications to qualify.

ASCS state committees will pick participants for county demonstration projects nationwide, with five counties per state and 20 farms per county allowed. Among the provisions that may be included in the ICM systems are pest management, crop rotations, biological pest control services, ridge-till, planting of host crops, cover crops, and leaf tissue analysis.

SCS software tailors LISA

To simplify planning for sustainable agricultural systems, the Soil Conservation Service has developed a software package called the Cost and Return Estimator (CARE).

CARE has been designed to provide producers, farmers, and landowners a format for making decisions on low-input, sustainable agricultural practices on an individual-farm basis.

CARE was developed to help land users compare and contrast the alternatives that go into current farming methods. It is designed to generate costs and returns for a land user's present practices and use a variety of scenarios that might affect input usage, crop yields, and ultimately the farmer's profits.

Calculations are made beginning with a producer's base budget. This budget is developed by the producer and SCS personnel and is the foundation for customizing a set of cost and returns under a given scenario. Such items as machinery costs, levels of usage, crop acreage and type, fuels, irrigation analysis, insurance, inputs, and a variety of other factors go into the formula for developing a picture of an individual farmer's situation. Using CARE can help land users better understand and reap the benefits of low-input, sustainable agriculture, the agency says.

The Soil Conservation Service has released CARE to all automated field offices in the United States; it is also available free of charge from Douglas Christianson at the Soil Conservation Service, Midwest National Technical Center, 100 Centennial Mall North, Lincoln, Nebraska 68508; telephone, (402) 437-5384.

Administration's 1991 budget released

The Bush Administration's 1991 budget, sent to Congress in early February, contains an allocation of $48.7 billion for U.S. Department of Agriculture programs.

Research is among the areas getting a boost in the document. A $1 billion allowance to go partially to USDA for research on global environmental change is a priority for the administration. "The USDA will make a significant contribution to the President's initiative on global change," Secretary of Agriculture Clayton Yeutter said in a recent USDA press release. "All of us have an obligation to engage in more research in this area," he said.

Other research projects include low-input agriculture; relationship of human health to diet and food safety; natural plant and pest disease resistance; biomass for energy production; increased forest productivity; and genetic engineering.

The Conservation Reserve Program will be getting $2.3 billion in funding, compared to the $1.8 billion in fiscal year 1990, if the administration has its way, "which should get us up to our 40-million-acre objective we have for the Conservation Reserve," Yeutter said.

On the negative side, federal crop insurance or disaster payment programs will come up short in 1991. Yeutter says that one program or the other will have to go because "we can't afford two [programs]," he said. Since 1980, the federal government has spent $5 billion on subsidizing federal crop insurance and $8 billion on federal disaster relief, a cost that Yeutter doesn't think belongs on the books.

Commodity testing in market channels will begin to provide USDA with a statistically reliable data base on the actual amounts of pesticide residues in food, and a major food safety initiative will occur.

The Farmer's Home Administration should get $400 million, the administration says, to help farmers who need operating loans. The loans will have a buy-down interest rate subsidy provision so that more borrowers can qualify. This buy-down rate may bring interest rates down as much as three percentage points. USDA will have a whole menu of loan programs available through FmHA in 1991, including direct loans, guaranteed loans at commercial rates, and guaranteed loans with interest rate buy-downs.

Other USDA projects and their funding requests include the "America the Beautiful" reforestation project, a voluntary, private-sector program that is projected to result in the planting of more than 1 billion trees a year in urban and rural areas, $175 million; the Agricultural Conservation Program, $176 million; and initiatives for enhancement of the environment, including a joint U.S. Fish and Wildlife Service-USDA program that will be used to enhance fish and wildlife habitat, reduce soil erosion, and enhance the biological environment of rural America, $2 billion.

Wetlands agreement gets slow start

What appeared to be a precedent-setting agreement on a no-net-loss wetland policy by the Bush administration has turned into a question mark in the minds of some environmentalists.

The policy, aimed at stopping all development on wetland areas, was created in a memorandum of agreement between the U.S. Environmental Protection Agency and the U.S. Army Corps of Engineers last November. But opposition from developers, oil companies, and from within the Bush administration has slowed its approval,

despite objections from EPA Administrator William K. Reilly and environmentalists.

With only 100 million of the estimated 250 million original acres of wetlands in the U.S. remaining, environmentalists are concerned about the continuing loss of 300,000 to 400,000 acres of wetlands in the United States each year. Agriculture, accounting for about 87 percent of the wetland destruction, is being blamed. Wetland drainage for farming purposes is not covered by federal law, although the Conservation Title's swampbuster provision has put severe limitations on those interested in participating in federal farm programs.

Throughout the debate, the document has been altered from its original form to account for the interests of developers and local governments who felt that the original agreement put too many restrictions on land use.

The agreement has been signed by EPA Administrator Reilly, who says that this is not a diversion from President Bush's no-net-loss policy. Quoted in the *Washington Post*, White House spokesman Alixe Glen said that EPA and the Army Corps of Engineers were happy with the agreement and that there was no objection on either front. The Bush Administration is presently seeking to develop a more broad-based policy that will comprehensively cover wetlands issues.

Farm bill stirs debate

Debate swirls in Washington, D.C. these days over the 1990 farm bill; a host of recommendations and reactions from farmers, researchers, environmentalists, legislators, and others have been laid on the table thus far in the process of attempting to compose one of the nation's most significant pieces of conservation legislation.

In February, the U.S. Department of Agriculture published its proposals for the first farm bill of the decade. These proposals outline the administration's standards for U.S. agricultural, conservation, and environmental programs in a list of more than 60 recommendations.

The set of proposals is broad-based. Covered are a range of issues vital to U.S. agriculture, including international marketing, price supports, crop disaster assistance, science and research, and, particularly, conservation and environmental actions that build on the Conservation Title of the 1985 Food Security Act.

The compliance provisions of that title—swampbuster, sodbuster, and conservation compliance—will remain in place if USDA has its way, as will the Conservation Reserve Program, which to date has met the goal of long-term natural resource protection by enrolling nearly 34 million acres of highly erodible cropland. However, sustaining the soil erosion control achieved thus far and maintaining the vegetative cover already planted on CRP is critical to some interests.

And apparently Secretary of Agriculture Clayton Yeutter agrees. So the benefits of the present program are not lost, the 1990 farm bill should contain a more highly refined CRP, says Yeutter, precisely targeted to support the greatest possible environmental improvements and to extend contracts when the present ones begin to expire.

Other areas of concern being addressed in this year's farm bill include the protection of surface water and groundwater from agricultural runoff, wetlands conservation, food safety standards, environmental education, and the enhancement of land protected under the annual acreage reduction programs.

With the scope of interests at stake, government agencies and special interest groups are standing in line to provide testimony and to assist in drafting the legislation. Following is a summary of the views put forth to date by USDA and the commodity and environmental groups on various topics encompassed by the debate:

Conservation Reserve Program. The CRP is a well-liked program, with many interests favoring maintenance of the present program and an extension of the 10-year contracts past their expiration dates.

USDA proposes that Congress supply additional support for bringing environmentally sensitive areas into the CRP, such as wetlands and riparian areas. Also, the agency wants farmers to be able to retain their crop bases if they leave CRP land under permanent cover when the contracts expire. For future contracts, USDA's proposal includes a requirement that the soil loss tolerance, or T level, be met if the land is returned to cropping.

The commodity groups, 20 of which have formed their own coalition to create a farm bill proposal, recommend that CRP land, if and when it comes back into production, be required simply to meet the same soil erosion standards as other highly erodible land, which in some cases is above the T level. The commodity groups also state that if 75 percent of a farm qualifies for enrollment in the CPR, the entire farm should qualify.

Conservation and environmental groups generally support the T standard for CRP land that might be returned to crop production.

On new land going into the CRP, the administration wants a cap of 40 million acres, while commodity and environmental groups want the cap raised to 50 million or more acres. All groups generally want to extend CRP authority through 1995.

Sodbuster/swampbuster and conservation compliance. Positions on these provisions vary widely. USDA simply states that an amendment to the Food Security Act of 1985 should explicitly include highly erodible land that is idled under annual commodity programs: highly erodible land must be fitted with a conservation program.

Commodity groups are interested in maintaining compliance implementation as it stands, with compliance violations only applying to farms found out of compliance. Currently, a tenant farmer can lose farm program benefits for all of his or her land even if only one landlord blocks an application for conservation plans. Landlords, on the other hand, are protected by the 1985 act if one or more of several tenants choose not to comply.

Environmental groups have an interest in strengthening the provisions and are calling for the toughening of some of the provisions with special amendments. One such amendment would extend compliance requirements to dairy program participants, while another would require producer participants who have been in commodity programs

for one year to remain in compliance for five years to retain benefits.

Sustainable agriculture and planting flexibility. A new program area, sustainable agriculture has made its way into USDA's proposals for this year's farm bill. Some analysts believe current farm policy discourages crop rotation, which increases soil fertility, and that more flexibility in planting may begin to remedy this problem.

USDA's proposals would allow farmers who plant soil-building crops on part of their base acres to receive deficiency payments for those acres, provided they do not harvest the crop. Producers would also be allowed to plant and still receive deficiency payments based on pre-1990 cropping histories.

Commodity groups are interested in allowing flexibility in crop production without the loss of base or payment yield and to guarantee deficiency payments even when soil-building crops are harvested. In addition, commodity groups are calling for an organic title that would establish a commission for defining and certifying an organic crop program and for an addition of an integrated crop management section to the Soil Conservation Service's technical manual.

Environmental groups are strong on sustainable agriculture. An amendment to commodity programs that allows flexible base acres and elimination of biases against conservation crop rotations is on their agenda. In addition, environmental groups would like to see USDA put greater emphasis on education and technical assistance for agricultural pollution source reduction, sustainable agriculture, and environmental protection. A call for the reform of federal food grading standards and an establishment of standards for pesticide residues and organically grown foods is also part of the environmental agenda.

Wetlands. USDA calls for expanding CRP eligibility criteria to include existing cropped wetlands and restorable cropped wetlands where restorable wetland values are high and the cost of restoration is not excessive. A new addition to the program would provide for permanent easesments on land under contract and for an allocation of 10 percent of CRP acres that could be covered through those easements.

Commodity groups would like to see easements as an option and a voluntary program to restore natural wetland characteristics to previously drained land. An amendment to the swampbuster provision that would exclude any land that produced a commodity for six years between 1975 and 1985 from the provision, with a minimum size under swampbuster, is another addition commodity groups also would like to see considered.

Environmental groups prefer to see the use of permanent or long-term easements to protect valuable wetlands and the restoration of wetlands currently used for agriculture. In addition, the act of drainage triggering the provision with landowners and giving the U.S. Fish and Wildlife Service the primary role in determining violations are amendments that environmental groups would like to see considered for swampbuster.

Multiyear set-aside. Currently, acreage that is idled under annual programs results in lost opportunities to protect natural resources. USDA proposes that producers be required to plant one-half of their acreage conservation reserve to annual or perennial cover crops each year. Crop cost-sharing and grazing provisions would be included in this proposal.

Commodity groups and environmental groups appear to support this issue as well. Environmental groups have also put forth the option of compensating producers who idle portions of program acres for three years with approved wildlife conservation practices.

Many sources say that creating an agriculture that is less polluting and making food safer will be the two biggest areas of debate surrounding the 1990 farm bill. One particular point of contention thus far has been the proposal that producers keep records of pesticide and nitrogen fertilizer applications, including the amounts, the crops applied to, and other patterns of usage that producers say is too strict and time-consuming. Organic labeling laws are an issue as well, but the laws are especially desired by farmers who take seriously the extra work required to produce organic farm products. Commodity groups are asking for a government commission to regulate such a program, while environmentalists are recommending strong national standards for organic foods, with a rigorous per-crop or per-farm certification program.

Tenth CRP signup not slated for 1990

Secretary of Agriculture Clayton Yeutter told members of the National Grain and Feed Association in January that a Conservation Reserve Program signup would not take place in February of this year and will not likely occur through the remainder of 1990.

For the past several years, CRP signups have occurred in February and

July or August. Nine signups have taken place over the past four years.

Yeutter was quoted as saying that when the signups do begin again past promotion of highly erodible land enrollment will likely give way to enrolling land that is prone to other environmental problems. He stated that additional signups would be more likely after the 1990 farm bill debate has ended.

Yeutter said USDA is committed to its goal of enrolling 40 million acres of cropland in the CRP. To date, 34 million acres have been enrolled.

Kasten unveils farm conservation program

U.S. Senator Bob Kasten (R-Wisc.) in March unveiled a comprehensive farm conservation package that he plans to introduce and that he says will assist in "protecting the future of America's agricultural productivity and wildlife."

Kasten predicts his Farm Stewardship Act of 1990 will help focus the entire farm bill debate presently being developed in Congress.

Based on four national resource themes, which include soil, water, wetlands, and wildlife, the bill contains initiatives that would (1) create an environmental stewardship program designed to protect the most fragile agricultural land; (2) rewrite the swampbuster provision in the Conservation Title of the Food Security Act of 1985, increasing the protection of wetlands; (3) create a new set-aside program that will create permanent cover for wildlife; (4) build whole-farm conservation programs into the federal agricultural assistance program, and (5) enhance soil conservation programs as a means of protecting the productive capacity of farms and reducing water pollution.

Kasten said the focus of his new proposal allows farmers the option of voluntarily enrolling in permanent conservation easements and makes economic uses of the land, such as leasing for hunting, periodic haying, or managed timber harvests, an additional option.

Air pollution damaging crops

Recent data from the U.S. Department of Agriculture and the National Crop Loss Network provides evidence that exposure to even moderate levels of ozone pollution can reduce crop yields by as much as 37 percent in rural areas, a part of the country previously thought of as not exceeding federal air pollution standards, the Izaak Walton League of America says.

Some commodities are more affected than others, according to IWLA. Many are highly altered with high levels of air pollution, which experts say can mean the difference between loss and profitability, especially when combined with drought and other crop-altering natural effects.

Food supplies could be affected as well, IWLA contends. In 1988, Americans ate more food than what they grew for the first time in history. Grain reserves have been on the decline, and wheat stocks are at their lowest since 1974. With high production needs at hand, some analysts are saying that clean air legislation should be a cause for concern among farmers as well as urban residents.

As a result of air pollution, the data show wheat yields in some areas have declined by as much as 37 percent; cotton yields, 20 percent; and soybean yields, up to 18 percent. Other crops, such as fruits and vegetables, can also be affected by ozone and air pollution, IWLA says.

California pesticide reporting goes into effect

California farmers who use pesticides are now required to make a full reporting of all of the pesticides they use, *according to the California* Department of Food and Agriculture.

"California is a leader in food safety and now becomes the first in the nation to require full reporting of pesticide use," said Jim Wells, assistant chief, Division of Pest Management, California Department of Food and Agriculture.

The new regulations, which went into effect January 1, require growers to report their use on a monthly basis to their county agricultural commissioner. The report must detail the kind and amount of pesticides used on specific fields and on what crops. In addition, all pesticide applied to golf courses, roadsides, ditches, and rights-of-way will be subject to reporting schedules.

Riparian enhancement program undertaken

The Izaak Walton League of America, Society for Range Management, and other private organizations and government agencies will be banding together with the Bureau of Land Management to sponsor volunteer riparian enhancement projects throughout the western states in 1990.

Projects will include replanting of vegetation, development of erosion control projects, replacing wildlife

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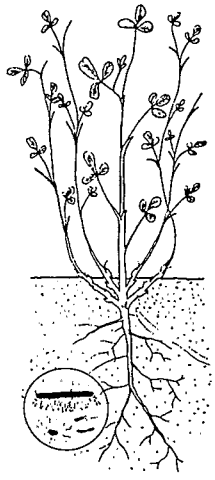

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habitat, and the cleanup of old trash and dump sites.

Riparian areas, which are vital and abundant on public land, are those fragile ecosystems that line the banks of rivers, lakes, springs, and other water bodies. They are an important natural resource for land managers and often have greater biological diversity than neighboring ecosystems.

Other sponsors of the project include the U.S. Forest Service, livestock and mining associations, Re-Tree International, Boy Scouts of America, state wildlife departments, riparian and watershed groups, and the University of Nevada at Reno.

Research on climate change proposed

Tracking changes in global climate is no easy task. To undertake such a task, however, the Bush Administration may increase funding for land- and space-based research programs in the fiscal year 1991 budget, according to a recent report by the Office of Science and Technology Policy's Committee on Earth Science.

The report, "Our Changing Planet: The FY 1991 Global Change Research Program," outlines an accelerated, focused research strategy designed to reduce key scientific uncertainties and to develop more reliable production of global change models. The research would be a major component in the development of the Bush administration's creation of national and international policies related to the global climate change issue.

The committee's report outlines a complete plan of earth- and space-based missions centered on research, data-gathering components, modeling activities, and projections aimed at realizing both short- and long-term scientific and public policy benefits.

Water quality projects planned

The U.S. Department of Agriculture will provide assistance through the Soil Conservation Service in 39 special water quality project areas beginning this year, USDA officials reported in February.

Educational and technical assistance will account for the bulk of the help directed at farmers and ranchers willing to develop conservation plans aimed at reducing nonpoint-source pollution.

"The Soil Conservation Service will be working closely with farmers and ranchers to reduce pollution from fertilizers, pesticides, animal wastes, nutrients, and sediment," commented Secretary of Agriculture Clayton Yeutter.

Accelerated technical assistance on the projects will be administered by state and county offices of USDA's Agricultural Stabilization and Conservation Service.

SCS unveils water plan

The Soil Conservation Service has released a water quality plan as part of the U.S. Department of Agriculture's effort to focus on water quality improvement projects. The five-year plan, called the Water Quality and Water Initiative, will initiate technical assistance to prevent and improve water quality problems.

The plan's creation was "in response to the increasing national concern about nonpoint-source impairment of water resources," says Wilson Scaling in the plan's introduction.

Four principal types of initiatives in the plan include (1) program applications, (2) technology development, (3) information dissemination, and (4) program assessment.

Fisheries on the decline

The American Fisheries Society in February issued a report on the status of declining indigenous fish populations in the United States.

The report, which documents the health of lakes, rivers, and stream systems, concludes: Despite a strong Endangered Species Act, agencies are unable to keep pace with the growing list of endangered habitats threatened by water use and development. In the United States alone, the study says, 62 fish qualify for endangered species status and another 84 species are threatened.

The report also contains information on the number of fish needing special protection, of which an increase of 45 percent in the number of rare fish occurred during the 1980s, the report states. California and Nevada have the most alarming record for an increase in rare fish, with more than 40 documented in each state.

Carl Sullivan, AFS executive director, stated, "Our conservation programs are not working. We need an increased commitment from political leaders in our country toward funding for recovery and habitat programs and overall protection of major ecosystems. We must protect biodiversity."

Problems with human pressures on water use and lack of distribution to aquatic habitats in need are cited as the

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primary cause of fish population declines. Forty fish are known to have recently become extinct as a result of environmental abuse, AFS contends.

Does best management have water right?

Can soil conservation practices contribute to groundwater contamination? According to a study being done at the University of Washington-Pullman, it is possible.

"Soil erosion control measures required by the Food Security Act increase the amount of water that soaks into the soil, and subsequently the infiltration of groundwater contaminants," says Larry King, a WSU agricultural engineer. King is leading a team of researchers trying to determine to what degree best management practices have an effect on groundwater contamination and nonpoint-source pollutants.

The research will focus on developing a computer model to determine how various farming practices affect water quality and how implemented conservation practices might improve or reduce the quality of nearby water sources.

"On the other hand, soil erosion measures increase the amount of soil organisms that break down contaminants, which could reduce the amount of residue headed for the water sources," King said.

Does the Pentagon need more land?

National Wildlife Federation President Jay Hair says the U.S. Department of Defense should take a closer look at its need to acquire more public land for military training.

Hair states that the department, which is requesting an additional 3 million to 7 million acres of land, should appoint an official who could handle such requests, a liaison the release says does not now exist.

Hair sent a letter to Defense Secretary Dick Cheney outlining the NWF perspective, which was prompted by the requests for more land in western states. NWF's main concern is that wildlife habitat and other important environmental resources could be threatened on the land acquired.

Other notes . . .

A $1.3 million program to enhance vital wildlife migration areas in the Playa Lakes region of the southern Great Plains is being established by a joint organization of state wildlife agencies, the U.S. Fish and Wildlife Service, Ducks Unlimited, Phillips Petroleum Company, and the National Wildlife Federation. The program will last for five years and enhance breeding grounds for waterfowl throughout the South.... **A savings of more than $500,000 in chemical inputs was demonstrated by Iowa State University Extension's Integrated Farm Management Demonstration Program in 1989,** with an average reduction of 25 pounds of nitrogen per acre on an enrolled 21,900 acres. Phosphorus and potassium accounted for another $56,000 in fertilizer savings on 3,500 acres.... **"Agriculture and the Environment: A Study of Farmer's Practices and Perceptions"** has been released by the American Farmland Trust. The report, which outlines current environmental practices being used by farmers, is based on nearly 500 interviews with farmers across the nation. The report is available for $3 in summary form or $10 in book form, from AFT, 1920 N Street N.W., Suite 400, Washington, D.C. 20036.... **The U.S. Environmental Protection Agency has announced several amendments to the labeled uses of atrazine,** stating that the herbicide must be more closely controlled because of its threat to groundwater sources.... **An agreement that could save certain species of plants from extinction** has been signed

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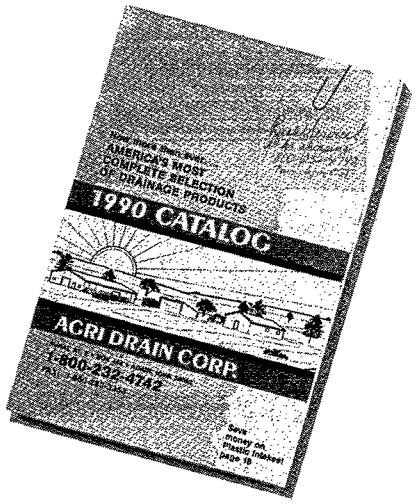

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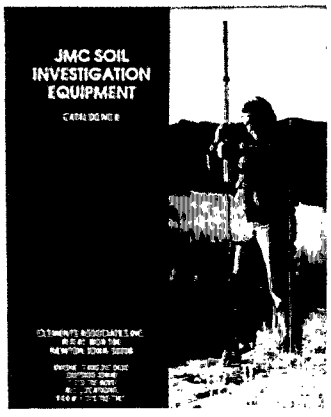

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by Bureau of Land Management officials and representatives from the Center for Plant Conservation. More than 50 of the 700 plant types found on BLM land are candidates for the endangered species plant listing under the Endangered Species Act.... **A bill extending federal protection to more than 594,000 acres of Colorado public land** has been introduced in the Congress by U.S. Senator Bill Armstrong (R-Colo.). The bill would designate the land as federal wilderness and, according to Armstrong, "resolve long-standing water right disputes throughout the state".... **Four new areas covering 15.5 million acres are now available for federal assistance under the Resource Conservation and Development (RC&D) Program.** Included are 19 counties in Pennsylvania, Tennessee, Utah, and West Virginia.... **Planting certain perennial grasses is a less costly and more environmentally sound method of reducing leafy spurge infestations on rangeland** says the University of Wyoming Extension Service.... **U.S. farmland prices are continuing to rise and will do so again this next year,** reports the American Society for Farm Managers and Rural Appraisers. A four percent gain is expected nationwide.... **Giving its approval to use of the Conservation Reserve Program for the protection of groundwater and wetlands,** the National Governors' Association Agriculture Committee said it also approves of farm bill language that gives farmers more planting flexibility. Some commodity groups have expressed reservations about such flexibility, suggesting that it might disrupt commodity production and prices.... **A long-term, joint venture with the Soviet Union to publish books and magazines** has been announced by Rodale Press of Emmaus, Pennsylvania. The first publication planned is a bimonthly farming magazine called *The New Farmer,* which will premier in the fall of 1990.... **3M Corporation was the recipient of the National Wildlife Federation's 1989 Corporate Conservation Environmental Award.** 3M was given the award for its Pollution Prevention Pays Program, developed to reduce hazardous waste outputs.... **No-Till Tiger Award winners for 1989 include** Bobby Boggess of Murray, Kentucky, in the dealer category; Dave Schertz, Washington, D.C., in the research category; and Don Clark, Frederickstown, Ohio, in the applicator category. The awards are sponsored by the Conservation Technology Information Center, *Farm Chemicals* magazine, and ICI Americas Inc.... **The 1990 fee for grazing livestock on federal land will be $1.81 per animal unit month,** which is defined as one cow and one calf; one horse; or five sheep or goats per month, according to a recent Bureau of Land Management release.... **National forest receipts paid to states in 1989 in lieu of real estate taxes will total $362 million.** The recipients include 41 states and Puerto Rico. Actual fiscal receipts collected from the sale and use of national forest resources totalled $1.44 billion.... **The Land Trust Exchange, a national organization of private land conservation organizations, has changed its name to the Land Trust Alliance** to more accurately reflect the new focus of the group that links together private organizations working on land issues.... **Soil Conservation Canada has established a Hall of Fame** recognition program for Canadians who have contributed to the cause of soil conservation. The first inductees will be honored at the organization's 1990 annual meeting. For more information, write Soil Conservation Canada, 275 Slater Street, Suite 500, Ottawa, Ontario K1P 5H9.... **Iowa State University's new Leopold Center for Sustainable Agriculture** was dedicated in February. The center is charged with identifying the environmental and socioeconomic impacts associated with agriculture and implementing educational programs through the ISU Extension Service.... **Consumer food prices would rise by 45 percent and the food supply would be cut in half if farmers could no longer use pesticides and fertilizers,** according to a study sponsored by the National Agricultural Chemicals Association and The Fertilizer Institute. Environmental pressures and degradation would increase without fertilizer use because of the additional plantings needed to meet domestic food demand, the study determined.... **Protection and maintenance of sensitive resources on public lands** is the goal of a memorandum of understanding signed recently by the Bureau of Land Management and The Nature Conservancy. Under the memorandum, the two parties will work to identify and protect public land that has high natural resource values, including land of exceptional ecological importance; areas of critical environmental concern; and locations of endangered or threatened species and rare plant communities.

People

New appointees to the National Public Lands Advisory Council of the U.S. Department of the Interior's,

Bureau of Land Management include **William Burnham**, of Boise, Idaho; **Robert List**, Reno, Nevada; **Maitland Sharpe**, Arlington, Virginia; **C. Chuck Hawley**, Anchorage, Alaska; and **Mark Murphy**, Roswell, New Mexico. Two reappointees include **Calvin Black**, Blanding, Utah, and **David Schaenen**, Billings, Montana.

Merle Doughty, former president of the Missouri Association of Soil and Water Conservation Districts was recently awarded the National Assocation of Conservation Districts Special Service Award.

Roger C. Dower has been named director of the Climate Research Program at the World Resources Institute. He was formerly head of the energy and environment program for the Congressional Budget Office.

Elizabeth Estill has been named director of the Recreation Management Staff with the U.S. Forest Service. Prior to her appointment, she was assistant director of the same staff.

Cooper Evans, special assistant to the president for agriculture, trade and food assistance, has been awarded the National Association of Conservation Districts Special Service award.

Stuart Finley has received the Communications Award from the National Association of Conservation Districts. Finley, a film-maker, is director of the Lake Bancroft Watershed Improvement District in Fairfax County, Virginia.

Dale Hathaway, vice-president of The Consultants International Group, Washington, D.C., has been named visiting senior fellow at the National Center for Food and Agricultural Policy, Resources for the Future.

Patricia Kearney has been named acting assistant secretary for natural resources and the environment in the U.S. Department of Agriculture. Replacing Kearney as Secretary of Agriculture Clayton Yeutter's chief of staff is **Gary Blumenthal**.

Ariel E. Lugo has received the U.S. Forest Service's Distinguished Science Award. Lugo is director of USDA's Forest Service Institute of Tropical Forestry in Puerto Rico.

Fernando Cesar Mesquita, outgoing head of the Brazilian Institute for Environmental and Natural Resources, has been named the recipient of the National Wildlife Federation's Conservation Service Citation for his efforts to halt the destruction of Amazonian rain forests and for establishment of "extractive reserves" for Brazil's rubber trappers.

Rikki Mitman, a former advertising agency professional, has joined the National Association of Conservation Districts as a marketing and member

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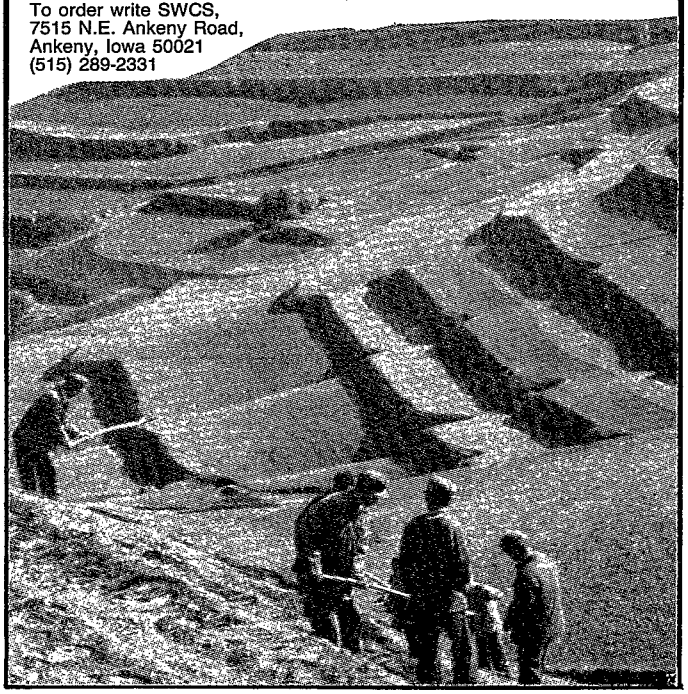

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services specialist at the organization's service center in League City, Texas.

James L. Plaster was given the National Association of Conservation District's Professional Service Award for 1990. Plaster is executive secretary for the Alabama State Soil and Water Conservation Committee.

Katherine H. Reichelderfer has been named a senior fellow at the National Center for Food and Agriculture Policy, Resources for the Future, in Washington, D.C. Reichelderfer was previously with the Economic Research Service.

Dale Robertson, chief of the U.S. Department of Agriculture's Forest Service, has been named River Conservationist of the Year by American Rivers, an organization dedicated to river preservation.

Leo Stroosnijder, has been appointed professor in soil and water conservation for rainfed agriculture in the semiarid tropics with the Department of Irrigation and Soil and Water Conservation, Wageningen Agricultural University, The Netherlands.

Gilbert F. White, Boulder, Colorado, was recently presented the Henry P. Caulfield Jr. Medal for exemplary contributions to national water policy by the American Water Resources Association.

Past-president Partain dies

Lloyd Partain, a former president of the Soil and Water Conservation Society, died March 10 in Pottstown, Pennsylvania. He was 84.

Partain retired in 1972 as the assistant to the administrator for environmental development with the Soil Conservation Service. He began work with SCS as a public information officer in 1935 and served in a variety of positions in both government and the private sector prior to his retirement.

Partain was president of SWCS in 1949 and received the prestigious Hugh Hammond Bennett Award in 1979.

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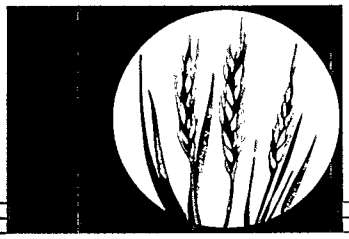

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June 2-7, Windbreaks and Agroforestry Symposium
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June 11-15, Design of Water Quality Monitoring Networks
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Contact: Thomas G. Sanders, Department of Civil Engineering, Colorado State University, Fort Collins 80523

June 14-17, World Agricultural Expo '90
New Zealand
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June 16-19, The Land Trust Exchange National Rally '90. "Strength through Diversity"
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June 25-28, Activated Sludge Process Control
Fort Collins, Colorado
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June 25-29, International Symposium on Tropical Hydrology and Fourth Carribean Islands Water Resources Conference
San Juan, Puerto Rico
Contact: Dr. Rafael Mundz-Cadelario, Water Resources Research Institute, University of Puerto Rico, Mayaquez Campus, P.O. Box 5000, Mayaquez, Puerto Rico 00709-5000; (809) 832-4040

July 9-11, The 1990 Watershed Symposium
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July 17-19, Principles of Groundwater Hydrology
Denver, Colorado
Contact: National Well Water Association, 6375 Riverside Drive, Dublin, Ohio 43017; (614) 761-1711

July 29-August 1, Soil and Water Conservation Society 45th Annual Meeting
Salt Lake City, Utah
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July, Climatic Risk in Crop Production: Models and Management or the Semiarid Tropics and Subtropics
Brisbane, Australia
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August 5-11, 19th World Congress of the International Union of Forestry Research Organization
Montreal, Quebec
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August 12-15, CONSERV '90: Water Supply Solutions for the 1990s
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August 15-18, National Sustainable Ag Forum
Lincoln, Nebraska
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September 9-12, Environmental Management: Challenges, Opportunities, Strategies
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Contact: American Society for Public Administration, 1120 G Street, NW, Suite 500, Washington, D.C. 20005; (202) 393-7878; FAX (202) 638-4952.

September 10-13, First International Symposium on Oil and Gas Waste Management Practices
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Contact: Mike Fitzpatrick, U.S. Environmental Protection Agency, OS-323 Office of Solid Waste, 401 M St. SW, Washington, D.C. 20460; (202) 475-6783

September 24-27, National Conference on Hydrocarbon Contaminated Soils
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October 6-11, Clay Minerals Society, 27th Annual Meeting
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October 7-9, Growing on the Delaware
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October 21-24, The Coastal Society 12th International Conference
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November 8-9, Third National Pesticide Research Conference
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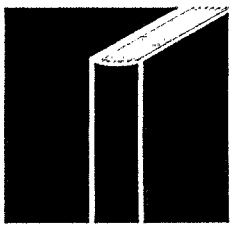

Alternative Agriculture. By Committee on the Role of Alternative Farming Methods, Board on Agriculture, National Research Council. 449 pp., 1989. National Academy Press, Washington, D.C. 20418. $19.95, paper; $29.95 hardbound.

Alternative farming techniques, such as fewer off-farm chemical inputs; crop rotations to reduce the use of pesticides; and, in general, much greater sensitivity to environmental or soil damage, are highlighted in a report of a special five-year study carried out under the auspices of the National Research Council by a 17-member committee chaired by John Pesek, Iowa State University. The committee's report, *Alternative Agriculture,* has been strongly endorsed by the Board on Agriculture, National Research Council. The board applauds the several alternative farming methods, which emphasize biological relationships, such as those between the predator and plants, and natural processes, such as nitrogen fixation, and rejects the so-called conventional agriculture, which, while being dramatically effective in increasing yields, has gained these increased yields at a high cost to society and has led to serious losses in quality of the country's soil and water resources.

The committee's report has not won accolades in all corners of the country. An independent environmental think tank, Resources for the Future, pointed out that low-pesticide farming may be less profitable and less ecologically beneficial than the NRC report suggests: "For the general run of farmers in the United States at the present time, alternative agriculture is not economically competitive. Although alternative agriculture methods may minimize pesticide pollution, they also place other strains on the environment, and in addition are financially risky."

I see no problem with any of the alternative agriculture goals; in fact, these are part and parcel of so-called conventional farming systems when properly managed:

► Priorize nitrogen fixation, nutrient recycling, and pest-predator relationships.

► Discourage inputs that have the greatest potential to harm the environment, the health of farmers, and the quality of food produced.

► Encourge greater use of biological and genetic potential of plant and animal species.

► Support cropping patterns and systems that ensure long-term sustainability and at the same time maintain production levels.

► Encourage much increased awareness of the need for conservation of soil, water, energy, and biological resources in a profitable and efficient cropping system.

A wide range of farming systems and practices are envisaged. The prudent use of agricultural chemicals is encouraged, as well as organic farming. Where appropriate, low-input, sustainable farming systems are included. High priority is given to diversified farming systems; they are generally more stable and resilient and also reduce risk, provide a hedge against drought and other natural factors, and should give the farmer greater leverage to respond to market place gyrations.

In contrast to the more highly focused organic farming systems or low-input, sustainable agriculture, the alternative farming proposal recognizes the need for farming systems to adapt specifically to the soil and climatic conditions prevailing in any one farming region.

The report notes that a wide range of government policies significantly influence farmers choices and generally work against environmentally neutral practices and the adoption of certain alternative farming systems. I must add here that agricultural policies in Canada have only very rarely been conservation neutral, and I know of no instance when they have been conservation positive.

The report recommends that serious consideration be given to regulatory change to ensure that more rapid progress can be made toward the development of safer guidelines for use of agricultural chemicals. In particular, greater emphasis must be placed on attaining a balance between the cost of health and environmental consequences of each pesticide and its benefits to production agriculture. Reference is rightly made to the Delaney paradox, an NRC report published in 1987 that included detailed recommendation for a consistent policy of regulating pesticide use.

The study strongly suggests that a systems approach to research is essential. Agricultural research to date has been a major pillar supporting crop production in the United States. Regrettably, on-farm research to evaluate interactions between crop rotations, tillage methods, pest control, and nutrient cycling has been almost nonexistent. Farmers need to understand these interactions. Developmental research and extension have not focused on integrating new knowledge into practical farming systems. The proposed alternative farming systems, rather than rejecting modern agricultural science as organic farmers often tend to do or leaving a major portion of the new technology on the shelf as low-input, sustainable agriculture suggests, strongly recommends that the fullest use of new technology must be encouraged through the integration of the new technology into current conventional agriculture. By doing so in a system mode, the study forecasts less use of agricultural chemicals, thus lowering input costs and minimizing the risk of environmental damage.

The report repeatedly underscores the following: Alternative farming practices, to be successful, require better trained labor, much improved management skills, and more detailed and timely information relating both to production and marketing aspects of farming. My experience would suggest that those farmers in western Canada who have seriously attempted to adopt "sustainable" farming methods and have failed did so because they did not have a sufficient understanding of agricultural science to enable them to integrate, without unacceptably high risk, the new (or alternative) technology into a system compatible with their soils, the prevailing climate, and available on-farm resources.

The committee expresses concern that the retirement and attrition of scientists capable of bridging the gap between the laboratory and the field will materially reduce the country's ability to quickly apply new alternative agriculture technology at the farm gate. Few young

scientists are pursuing careers in scientific agriculture, let alone participating in interdisciplinary or systems research. It places a major part of the blame on higher education institutions, the peer review system, and funding. I would counter this statement by pointing out that educational institutions, particularly colleges of agriculture, have been and are turning out scientists who are better qualified than ever to meet the needs of the agriculture industry, but employers and funding agencies have not recognized the value of interdisciplinary or systems research and development, other than giving it a kind of motherhood support. In particular, here in western Canada, there is not strong support for much-needed on-farm systems research.

The report strongly recommends the conduct of on-farm research and developmental, field-scale farming-systems studies, which are regionally focused, multidisciplinary, long-term, and have high visibility. Substantial new funding—the report recommends at least $40 million—should be added to the U.S. Department of Agriculture's competitive grants program. Priority in this program is to be given to basic as well as applied multidisciplinary research. Suggested priorities for the competitive program include nutrient cycling research related to increasing efficiency of nutrient use, the role of alternative tillage systems in weed control, new pest strategies, the study of the interaction between crop rotation and environmental quality, the development of improved crop and livestock species through genetic engineering, improved farm equipment design, the economics of alternative farming systems, and the development of computer software systems to aid farmers in making management decisions.

The final section of the report is intended to provide insight into how the real world works. This is perhaps the weakest portion of the report. With the exception of a large cattle ranch in Colorado, there are no unirrigated examples of successful alternative farming throughout the very large semiarid and arid regions of the country. Perhaps none exist; "low input" and "organic" agriculture dominated the farming systems in western Canadian agriculture for the first 50 to 75 years, and during this time extensive soil degradation occurred. Thousands of tons of essential plant nutrients, in particular nitrogen and phosphorus, which came from rich soil reserves, were exported. Erosion by wind and water, salinization, and structural breakdown are today estimated to cost farmers in the prairie region about $1 billion per year in lost annual production. Are their alternatives to the current farming systems in the Great Plains region of North America? Certainly, the kind of alternative farming systems suggested in the NRC report are not only unsustainable in the semiarid Great Plains region, but also will lead to further accelerated resource degradation.

I am convinced that the first generations of farming here on the prairies and perhaps also throughout North America must be replaced by a new generation of sustainable farming systems. Note that I do not use the term alternative farming systems. We can and will leverage our way into these new systems with considerable optimism because much of the technology is now on the shelf. The farmer or, for that matter, the policymakers who continue to operate on the 20th century format are indeed at risk and will likely be a casualty as agriculture in North America moves into the 21st century. *Alternative Agriculture* provides some insight into the kinds of changes that may take place. The most noteworthy chapter is that entitled "Research and Science," and this is recommended reading for all.—*D. A. Rennie, College of Agriculture, University of Saskatchewan, Saskatoon, S7N 0W0.*

The Greening of Aid: Sustainable Livelihoods in Practice. Edited by Czech Conroy and Miles Litvinoff. 302 pp., 1988. Earthscan Publications, London, England WC1H ODD. £8.95 + £1 postage.

The International Institute for Environment and Development (IIED) has a good record of stimulating ideas, one of which is reported in *The Greening of Aid: Sustainable Livelihoods in Practice.* This book is based on the papers produced for the "Only One Earth Conference on Sustainable Development," organized by IIED at Regent's College, London, in April, 1987.

Sustainable development was the central theme of the conference and each of the commissioned case studies reported at the conference was chosen for its relevance to the issue of sustainability. The book consists of 34 such studies arranged in six groups, with a rapporteur's overview and summary of the papers in each group. The groups are as follows: "Sustainable Rural Livelihoods: A Key Strategy for People, Environment, and Development," rapporteur Robert Chambers; "Sustainable Rural Livelihoods: Enhanced Resources Productivity," rapporteur John Michael Kramer; "Mass Production or Production by the Masses?" rapporteur Marilyn Carr; "Planning Techniques for Sustainable Development," rapporteur Colin P. Rees; "Human and Institutional Development," rapporteur David Butcher; and "Human Settlements," rapporteur Yves Cabannes.

The selection of experienced specialists as the authors and rapporteurs resulted in a high standard of technical writing, which has been skillfully edited into book format. *The Greening of Aid: Sustainable Livelihoods in Practice* deserves to be read by everyone concerned about the environmental issues of development.—*N. W. Hudson, International Center for Soil Conservation Information, Ampthill, England.*

The Small Town Planning Handbook. By Thomas L. Daniels and John W. Keller with Mark B. Lapping. 167 pp., 1988. The American Planning Association, Chicago, Illinois 60637.

The Small Town Planning Handbook is of special value to residents in small towns or rural areas who have had no previous exposure to the activity called community planning. The book is divided into two parts. The first, "Creating a Town Plan," consumes more than half of the book and describes in great detail what data are needed and should go into formulation of a town plan. The presentation is

rather pedantic and uses newly invented terminology, such as "miniplan" and distinct from "minor plan" and "major plan." The extensive listings of statistical data needed for making a plan may appeal to students of community planning, but they may also discourage the typical citizen-planner.

Part two deals with "Putting the Town Plan Into Action." The subjects of zoning, subdivision regulations, and capital improvements programs are covered in detail. Most of the advice given is in good, understandable language, adhering to sound planning principles that most professional planners would support. I offer one note of caution however. I would not support the recommendation to negotiate "density bonuses" with developers to improve their esthetic design. Zoning is correctly described as a "police power," and varienaces from the standards should not be "for sale."

The emphasis given to plan implementation is important. The authors provide a realistic argument that plans do not implement themselves. It takes a determined, continuing effort on the part of a broad array of citizens to go from a plan on paper to actual accomplishments on the ground. That point is well made in the book and provides the most important reason for putting it in the category of recommended reading.—*WARREN T. ZITZMANN, Falls Church, Virginia.*

General

Development and the National Interest: U.S. Economic Assistance into the 21st Century. 158 pp., illus., bibliog., 1989. Agency for International Development, Washington, D.C. 20523.

Economic Instruments for Environmental Protection. 132 pp., refs., app., 1989. OECD Publications and Information Center, Washington, D.C. 20036-4095. $23.50.

Here to Stay: A Resource Kit on Environmentally Sustainable Development. 1989. DEC Book Distribution, Toronto, Ont. M5T 1R4. $25.00, plus 10% postage/handling; 20% outside Canada.

The Complete Guide to Environmental Careers. 350 pp., illus., bibliog., index, 1989. The CEIP Fund, Boston, Mass. 02111-1907. $24.95, cloth; $14.95, paper.

Sustainable Development: A Guide to Our Common Future. By Gregory G. Lebel and Hal Kane. 77 pp., 1989. Oxford University Press, New York, N.Y. 10016.

Communities at Risk: Environmental Dangers in Rural America. By Albert J. Fritsch. 40 pp., illus., 1989. Renew America, Washington, D.C. 20036.

Toward a Common Future: A Report on Sustainable Development and Its Implications for Canada. By Michael Keating. 47 pp., illus., refs., 1989. Environment Canada, Ottawa, Ontario.

Natural Resources for the 21st Century. Edited by R. Neil Sampson and Dwight Hair. 349 pp., illus., refs., index, 1990. Island Press, Washington, D.C. 20009.

Economics of Natural Resources and the Environment. By David W. Pearce and R. Kerry Turner. 378 pp., illus., refs., index, 1990. The Johns Hopkins University Press, Baltimore, Md. 21211. $42.50, hardcover; $19.50, paperback.

The Pilgrim and the Cowboy. By Paul McKay, 214 pp., 1989. McGraw-Hill Publishing Co., New York, N.Y. 10011. $18.95

Agriculture

Selenium in Agriculture and the Environment. L. W. Taylor, editor. 233 pp., 1989. Book Order Department, SSSA, ASA Headquarters, 677 South Segoe Rd., Madison, Wisc. 57311. $24.00 $2.40 per book for postage outside the United States.

Acreage Allocated to Conservation Tillage Practices in Mississippi, 1985-1988. By Stan R. Spurlock and Sukant K. Misra. 9 pp., illus., tbls., 1989. Bull. 957. Mississippi Agricultural and Forestry Experiment Station, Mississippi State, 39762.

World Agriculture: Factors Influencing Trends in World Agricultural Production and Trade. 106 pp., illus., tbls., app., 1989. GAO/RCED-89-1. U.S. General Accounting Office, Gaithersburg, Md. 20877.

Choices for the Heartland: Alternative Directions in Biotechnology and Implications for Family Farming, Rural Communities and the Environment. By Chuck Hassebrook and Gabriel Hegyes. 113 pp., 1989. Center for Rural Affairs, Walthill, Nebr. 68067.

Resource Audit and Planning Guide for Integrated Farm Management. 1989. Center for Rural Affairs, Hartington, Nebr. 68739. $5.00.

Risks, Challenges and Opportunities: Agriculture, Resources and Growth in a Changing Central Valley. 95 pp., illus., 1989. American Farmland Trust, San Francisco, Calif. 94107.

Influence of Soil Moisture on Herbicide Performance. By Joe E. Street and Theodore C. Miller. 3 pp., illus., refs., 1989. Vol. 14, No. 20. Mississippi Agricultural and Forestry Experiment Station, Mississippi State, 39762.

Alternative Agriculture. 448 pp., illus., refs., tbls., gloss., index, 1989. National Academy Press, Washington, D.C. 20418. $19.95.

Strategies for Alternative Crop Development: Case Histories. 72 pp., 1989. Educational Development System, University of Minnesota, St. Paul, 55108. $10.00.

The Farm Policy Game Play by Play. By Lauren Soth. 277 pp., 1990. Iowa State University Press, Ames, 50010. $29.95, plus $2.00 for postage for first copy, 75 cents for each additional copy.

Yield and Quality of Winter Annual Forages. By Julio C. Medal and John A. Balasko. 35 pp., illus., refs., tbls., 1989. Bull. 701. West Virginia University Agricultural and Forestry Experiment Station, Morgantown, 26506-6125.

Soils

The Extent of Soil Erosion. Topics in Applied Resource Management in the Tropics. Vol. 1. 201 pp., illus., tbls., 1989. DITSL-Topics, P.O. Box 1652, Steinster. 19, D-3430 Witzenhausen 1, West Germany. $38.00.

Soils and Their Management: A Sino-Euopean Perspective. Edited by E. Maltby and T. Wollersen. Proceedings, Workshop jointly organized by the People's Republic of China and the EEC, China, April 1988. Elsevier Science Publishing Co., Inc., New York, N.Y. 10159. $86.50.

Water

Channelized Rivers: Perspectives for Environmental Management. By Andrew Brookes. 326 pp., illus., refs., app., indxes, 1989. John Wiley & Sons, Inc., Somerset, N.J. 08875-1272. $79.95.

Law of Water Rights and Resources. By A. Dan Tarlock. Tbls., index, 1988. Clark Boardman Co., Ltd., New York, N.Y. 10014. $95.00.

Water Resource Management: Integrated Policies. 200 pp., app., bibliog., 1989. OECD Publications and Information Centre, Washington, D.C. 20036-4095. $24.00.

Water for Agriculture: Facing the Limits. By Sandra Postel. 54 pp., illus., refs., 1989. Worldwatch Paper 93. Worldwatch Institute, Washington, D.C. 20036. $4.00.

The Water Encyclopedia (2nd edition). By Frits van der Leeden, Fred L. Troise, and David Keith Todd. 800 pp., illus., tbls., maps, 1990. Water Information Center, Inc., Plainview, N.Y. 11803. $125, plus $3 for postage and handling.

Rivers at Risk: Citizen's Guide to Hydropower. By John D. Echeverria, Pope Barrow, and Richard Roos-Collins. 220 pp., 1990. Island Press, Covelo, Calif., 95428. $29.95, cloth; $17.95, paper, plus $2.00 for shipping and handling.

Markets for Federal Water: Subsidies, Property Rights, and the Bureau of Reclamation. By Richard W. Wahl. 308 pp., illus., refs., tbls., app., index, 1989. Resources for the Future, Baltimore, Md. 21211. $30.00, plus $3.00 postage and handling.

Land Use

Report on the Seminar on Operational Use of Satellite Images in Development Planning. By Qalabane K. Chakela. 28 pp., plus apps., 1988. Report No. 15. SADCC Coordinator, Soil and Water Conservation and Utilization, Ministry of Agriculture and Marketing, P.O. Box 24, Maseru 100, Lesotho.

Environmental Policy Benefits: Monetary Valuation. 84 pp., illus., bibliog., 1989. OECD Publications, Washington, D.C. 20036-4095. $20.00.

Federal Manual for Identifying and Delineating Jurisdictional Wetlands. 76 pp., plus illus., refs., gloss., apps., 1989. U.S. Government Printing Office, Washington, D.C. 20402.

Saving America's Countryside: A Guide to Rural Conservation. By Samuel N. Stokes, A. Elizabeth Watson, Genevieve P. Keller, and J. Timothy Keller. 320 pp., appx., illus., maps, 1989. Johns Hopkins University Press, Baltimore, Md. 21211. $42.50, hardcover; $16.95, paperback.

Range Development and Improvements (third edition). By John F. Vallentine. 524 pp., illus., refs., app., indexes, 1989. Academic Press, Inc., Troy, 68379. $45.00.

The Evolving Use and Management of the Nation's Forests, Grasslands, Croplands, and Related Resources. By John Fedkiw. 66 pp., illus., refs., 1989. Gen. Tech. Rpt. RM-175. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo. 80526.

Situations and Strategies in American Land-Use Planning. By Thomas K. Rudel. 166 pp., illus., refs., tbls., apps., index, 1989. Cambridge University Press, New York, N.Y. 10022. $37.50.

Land Use Transitions in Urbanizing Areas: Research and Information Needs. Proceedings, Workshop, Economic Research Service, USDA, and The Farm Foundation. Edited by Ralph E. Heimlich. 217 pp., illus., refs., 1989. Economic Research Service, USDA, Washington, D.C. 20005-4788.

Land Use Decisions: Issues in the Evolution of Wisconsin's County Forest Program 1963-1985. By Duncan A. Harkin. 98 pp., illus., apps., 1988. University of Wisconsin-Extension, Madison, 53706.

Are There Any Public Lands for Sale? 16 pp., 1989. Superintendent of Documents, Washington D.C. 20402-9325. $1.00.

Forests

The Status of Forest Management Research in the United States. By Donald G. Hodges, Pamela J. Jakes, and Frederick W. Cubbage. 16 pp., illus., refs., 1988. Gen. Tech. Rpt. NC-126. Forest Service, North Central Forest Experiment Station, St. Paul, Minn. 55108.

Forestry Sector Intervention: The Impacts of Public Regulation on Social Welfare. By Roy G. Boyd and William F. Hyde. 295 pp., illus., tbls., indexes, 1989. Iowa State University Press, Ames, 50010. $34.95.

Seedling Nutrition and Irrigation. The Container Tree Nursery Manual, Volume Four. By Thomas D. Landis, Richard W. Tinus, Stephen E. McDonald, and James P. Barnett. 119 pp., illus., refs., index, 1989. Agriculture Handbk. 674. U.S. Forest Service, Washington, D.C.

Seventh Central Hardwood Forest Conference. Proc., Southern Illinois University at Carbondale, March 5-8, 1989. Edited by George Rink and Carl A. Budelsky. 313 pp., illus., 1989. Gen. Tech. Rpt. NC-132. North Central Forest Experiment Station, U.S. Forest Service, St. Paul, Minn. 55108.

How to Save Trees During Construction. 8 pp., illus., 1989. National Arbor Day Foundation, Nebraska City, Nebr. 68410.

Discovering New Knowledge About Trees and Forests. 114 pp., illus., 1989. Gen. Tech. Rpt. NC-135. North Central Forest Experiment Station, Forest Service, St. Paul, Minn. 55108.

Shading Our Cities: A Resource Guide for Urban and Community Forests. Edited by Gary Moll, and Sara Ebenreck. 333 pp., 1989. American Forestry Association, Washington, D.C. 20013. $19.95, paperback; $34.95, cloth, plus $2.00 shipping.

Site Index Curves for Forest Tree Species in the Eastern United States. By Willard H. Carmean, Jerold T. Hahn, and Rodney D. Jacobs. 142 pp., illus., refs., apps., index, 1989. Gen. Tech. Rpt. NC-128. North Central Forest Experiment Station,

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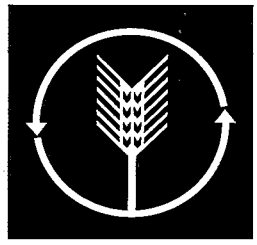

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Wildlife, Forests, and Forestry: Principles of Managing Forests for Biological Diversity. By Malcolm L. Hunter, Jr. 370 pp., illus., refs., apps., indexes, 1990. Prentice Hall, Inc., Englewood Cliffs, N.J. 07632.

Law, Legislation and Politics

Zoning and the American Dream: Promises Still to Keep. Charles M. Haar and Jerold S. Kayden, editors. 386 pp., illus., app., index, 1989. American Planning Association, Washington, D.C. 20036.

Recreation

Research Issues Related to Recreation Enterprises for the Private Landowner. By Dale Colyer and Dennis K. Smith. 14 pp., refs., 1990. R. M. Publications No. 90/01. West Virginia University Extension Service, Morgantown, 26506-6125.

Research Issues: Related to Recreational Access. By Lawrence w. Libby. 13 pp., refs., no date. R.D. No. 747. West Virgnia University Extension Service, Morgantown, 26506-6125.

Reclamation

Surface Coal Mining Reclamation: 10 Years of Progress, 1977-1987. 50 pp., illus., 1987. U.S. Government Printing Office, Washington, D.C. 20401. $4.25.

Surface Mining: Operation of the Applicant Violator System Can be Improved. GAO/AFMD-89-31, 1989. U.S. General Accounting Office, Gaithersburg, Md. 20877. First five copies free, additional copies are $2.00 each.

Waste Management

Wastes in Marine Environments. 312 pp., illus., ref., index, 1987. U.S. Government Printing Office, Washington, D.C. 20402. $13.00.

Hazardous Waste Site Management: Water Quality Issues. Report on a Colloquium sponsored by the Water Science and Technology Board. 212 pp., illus., apps., index, 1988. National Academy Press, Washington, D.C. 20418. $24.50.

Treatment of Hazardous Waste Leachate: Unit Operations and Costs. By J. L. McArdle, M. M. Arozarena, and W. E. Gallagher. 111 pp., illus., refs., 1988. Noyes Publications. Park Ridge, N.J. 07656. $36.00.

Hazardous Waste Site Remediation: The Engineer's Perspective. 422 pp., illus., refs., bibliog., index, 1988. Van Nostrand Reinhold, New York, N.Y. 10003. $38.95.

Waste: Choices for Communities. Concern, Inc., Washington, D.C. 20009. $3.00.

The Role of Waste Minimization (volume 1). By Domenic Forcella. 85 pp., apps., 1989. National Governors' Association, 444 North Capitol Street, Suite 250, Washington, D.C. 20001-1572. $15.00.

Pesticides

MSDS Reference for Crop Protection Chemicals. 1,412 pp., plus updates. John Wiley & Sons, New York, N.Y. 10158. $145, available by subscription.

The Standard Pesticide User's Guide. By Bert L. Bohmont. 498 pp., illus., gloss., apps., indexes, 1990. Prentice Hall, Englewood Cliffs, N.J. 07632.

For Our Kids' Sake: How to Protect Your Child Against Pesticides in Food. By Anne Witte Garland. 87 pp., illus., refs., gloss., 1989. Sierra Club Books, San Francisco, Calif. 94109. $6.95 plus $3.00 for postage and handling.

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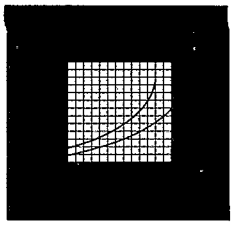

Nitrogen status of corn after alfalfa in 29 Iowa fields

N. M. El-Hout and A. M. Blackmer

*ABSTRACT: Excessive applications of nitrogen (N) fertilizer can occur when farmers do not give adequate credits for N supplied by legumes. Newly developed soil and tissue tests were used to evaluate the N status of 29 fields of first-year corn (*Zea mays *L.) after alfalfa (*Medicago sativa *L.) in northeastern Iowa in 1987. Unlike other tests that have been used, these tests have the ability to characterize degrees of N excess. The tests showed that most farmers had applied more N fertilizer than needed to attain maximum yields. The soil test showed that 25 of the 29 fields had nitrate concentrations greater than optimal concentrations. Seventeen of the 29 fields had at least twice the critical concentration of soil nitrate, and 6 of the 29 fields had at least three times this concentration. The tissue test supported these findings. Most farmers could have increased their profits and decreased the potential for groundwater contamination if they had given more appropriate credits for N supplied by the alfalfa. Soil and tissue tests that can characterize degrees of N excess during corn production can be used to demonstrate the economic and environmental benefits that can be obtained by giving these credits.*

INPUTS of nitrogen (N) are essential for profitable agricultural systems. Rotations with legumes provided the major N input into agriculture until the advent of commercially fixed N fertilizers, which have provided abundant supplies of relatively inexpensive N in recent decades. These fertilizers essentially have eliminated the problem of N deficiency during crop production and have helped to provide the abundance of food and fiber currently enjoyed by developed nations. There is mounting concern, however, that large N inputs for crop production may increase the concentration of nitrate in groundwater (*2, 6, 8, 11*). Especially in areas where concentrations of nitrate in groundwater are increasing, there is need for greater efforts to avoid applying excessive amounts of fertilizer N.

It is difficult to define what rates of fertilization are excessive because such a definition often requires value judgments concerning the relative importance of agricultural productivity and groundwater quality. However, fertilization rates higher than those needed to attain maximum yields can be considered excessive without making value judgments. Because excessive fertilization decreases the profitability of crop production, there are economic as well as environmental incentives for avoiding such excesses.

The economic incentive for avoiding excessive N applications is relatively great in corn (*Zea mays* L.) production because N fertilizers represent a major expense for corn producers. There is evidence, however, that farmers often apply excess N fertilizer because they do not adjust rates of fertilization for N supplied by legumes. Recent studies reveal that many groups providing N fertilizer recommendations to farmers do not include such adjustments in their recommendations (*4*) and that producers often ignore these adjustments when they are recommended (*5, 6, 7, 12*). Because legumes often leave substantial amounts of N for subsequent crops, there is an obvious need for new ways to demonstrate the economic and environmental benefits that can be obtained by adjusting fertilization rates for N supplied by legumes.

In our study, we used newly developed soil and tissue tests to evaluate the N status of corn crops in fields under production agriculture. The soil and tissue tests used here can characterize degrees of N excess during corn production and, therefore, can identify situations of excessive N application. The work was done in a region where concentrations of nitrate in groundwater have increased over the past 20 years (*9*).

N. M. El-Hout is a postdoctoral research associate and A. M. Blackmer is an associate professor in the Department of Agronomy, Iowa State University, Ames, Iowa 50111. *Journal Paper no. J-13358 of the Iowa Agricultural and Home Economics Experiment Station, Ames; project 2741. This project was supported in part by the Iowa Department of Natural Resources through Grant No. 87-6254-02.*

Study methods

Our study was conducted in 29 fields of first-year corn after alfalfa (*Medicago sativa* L.) in Bremer, Fayette, and Clayton counties in northeastern Iowa in 1987. To avoid consideration of N management practices when selecting these fields, we contacted local sales representatives of a particular corn hybrid (Pioneer 3475) and asked for names of farmers who purchased this hybrid and grew alfalfa. We contacted the farmers and identified those who planted this hybrid after alfalfa. The farmers were contacted only after they had fertilized and planted their fields. They were asked to supply information regarding cropping history, fertilizer and manure application rates, and other related information. Of all the farmers contacted, only one declined to participate.

We established two adjacent plots (12.2 m by 6 rows) in each field by placing flags to mark the corners of each plot. The plots were selected to represent an area of seemingly uniform soil on the predominant soil type in each field. We evaluated the N status of each plot using the late-spring soil test (*3, 10*). This test involves determination of nitrate concentrations in the surface 30-cm (12-inch) layer of soil when corn plants are 15 to 30 cm (6-12 inches) tall. Eight core samples (3.2 cm in diameter), taken to a depth of 30 cm, were composited to provide one sample for each plot.

We evaluated the N status of each plot also by a corn tissue test (*1*) that involves determination of nitrate concentrations in the lower stalk at physiological maturity, that is, shortly after black layering. Lower stalk sections, extending from 15 to 35 cm (6-14 inches) above the ground, were collected from 10 plants and composited to provide one sample for each plot.

We determined corn grain yields by hand-harvesting 9-m (30-foot) segments of the two center rows of each plot and adjusting to 15.5% moisture content.

Results of the soil test, tissue test, and yield measurements from the duplicate plots were averaged to indicate results for each

field. We developed a model relating observed soil nitrate concentrations to rates of N application and ages of the alfalfa stands preceding the corn using the GLM procedure described by Spector and associates (*13*).

Results and discussion

We selected the P3475 corn hybrid because it was used widely in the area and because we had extensive data concerning its response to N. We restricted the study to corn after alfalfa because alfalfa contributes substantial amounts of fixed N to subsequent crops and, therefore, provides a significant opportunity for demonstrating the benefits of giving appropriate N credits for legumes.

Below-normal rainfall and above-normal temperatures occurred during April, May, and June, but timely rainfall during July and August resulted in above-average yields during the study. Corn grain yields in the fields surveyed ranged from 8.7 to 13.2 Mg/ha (138 to 210 bushels/acre) and averaged 11.7 Mg/ha (187 bushels/acre).

The farmers indicated that they applied commercial N fertilizers at rates ranging from 6 to 227 kg N/ha (5 to 202 pounds/acre) and averaging 136 kg N/ha (121 pounds/acre). Seventeen of the 29 fields received hog or cattle manure during the previous year. The farmers indicated that two fields received "light" applications, six fields received "medium" applications, and nine fields received "heavy" applications of manure. Age of the alfalfa crop preceding the corn ranged from 1 to 6 years and averaged 2.9 years. Because farmers were contacted only after the fields had been planted, we could not obtain precise information about the amount and N content of the manure applied or the density of the alfalfa stand in each field.

The late-spring soil test showed that most fields surveyed had greater concentrations of nitrate than required to attain maximum yields (Figure 1). Blackmer and associates (*3*) found that 21 mg nitrate-N/kg soil was the critical concentration, that is, the concentration needed to attain maximum yields. They found that a range of 20-25 mg nitrate-N/kg soil should be considered optimal. Seventeen of the 29 fields had at least twice the critical concentration, and 6 of the 29 fields had at least three times this concentration. The concentration of soil nitrate was appreciably below the critical level in only one field. This field had a high population of weeds, which may have depleted soil nitrate early in the season and depressed final grain yield. Because a significant relationship was not observed between yields and nitrate concentrations greater than 21 mg nitrate-N/kg soil, this critical level seems appropriate for this study.

The concentrations of nitrate in the cornstalks at maturity showed that all fields surveyed had more available N than required to achieve maximum yields (Figure 2). Recent studies in Iowa (*1*) showed that 0.3 to 1.8 g nitrate-N/kg stalk should be considered optimal. This range was adequate to attain maximum yields in this study because no significant relationship was observed between yields and stalk nitrate concentrations. The higher-than-optimal concentration of stalk nitrate in the field having the lowest yields reflects the fact that weeds, rather than N availability, limited yields in this field.

Equation 1 explained 57% of the variability in observed soil nitrate concentrations (n) by considering rates of N application (f), years of alfalfa preceding the corn (y), and an interaction between these variables.

$$n = -16.80 + 0.63\,f - 0.001\,f^2 + 19.66\,y - 2.13\,y^2 - 0.08\,fy \quad [1]$$

This model was significant at the 0.001 level of probability. Linear and quadratic terms in the model were significant at the 0.05 and 0.15 levels of probability, respectively. The model was not improved by including rates of manure application. This was unexpected and probably reflects inadequate information about the quantity and N content of the manures applied.

The model showed that soil nitrate concentrations increased with an increase in age of the alfalfa in fields where only small amounts of N had been applied (Figure 3). Soil nitrate concentrations increased with an increase in the amount of fertilizer N applied, but the rate of increase diminished as age of the alfalfa increased. Such an interaction could occur if increases in soil nitrate concentrations (from alfalfa, manure, or fertilizer) caused greater percentages of this nitrate to be lost by leaching, denitrification, or immobilization. Greater immobilization of fertilizer N should be expected during decomposition of the older alfalfa stands, which probably had more grasses and higher carbon-to-nitrogen ratios.

The model suggests that across all rates of manure applications no commercial fertilizer was needed to attain the critical concentration of soil nitrate following 3 or more years of alfalfa. The amount needed for corn following 1 year of alfalfa was 40 kg N/ha (36 pounds/acre) and for corn following 2 years of alfalfa was 16 kg N/ha (14 pounds/acre). If farmers had used the rates of fertilization suggested by the model, the mean rate of N application would have been 13 kg/ha (12 pounds/acre), which is 123 kg/ha (110 pounds/acre) less than the mean rate of application indicated by the farmers. These calculations suggest that farmers could have increased the profitability of corn production and substantially reduced the potential for groundwater contamination if they had given more appropriate credits for the N supplied by the alfalfa.

The model indicates that the mean observed concentration of soil nitrate in corn fields following 3 or more years of alfalfa would have been 26 mg nitrate-N/kg soil if commercial N fertilizer had not been applied. This value is near the upper limit of the optimal range. It also is in agreement with results of a related study in the same area during 1987 (unpublished data). In the related study, we found an average concentration of 28 mg nitrate-N/kg soil with the late-spring soil test among seven fields (21 plots) in first-year corn after alfalfa that had

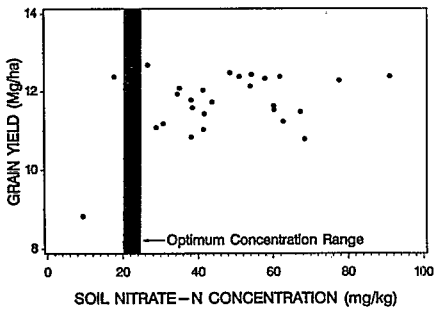

Figure 1. The relationship between corn grain yields and soil nitrate concentrations in 29 Iowa fields.

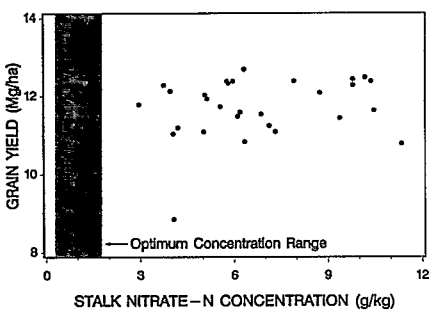

Figure 2. The relationship between corn grain yields and stalk nitrate concentrations in 29 Iowa fields.

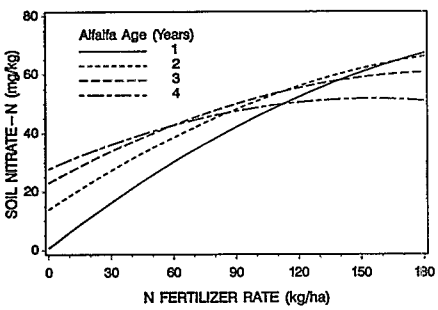

Figure 3. The relationship between soil nitrate concentrations and N fertilization rates for corn following various years of alfalfa.

received no fertilizer N or manure. We also found that corn grain yields were not significantly increased by the addition of N fertilizer to these seven fields. These findings suggest that the excess available N observed in this survey largely could have been avoided if farmers had adjusted rates of commercial fertilizer application for N supplied by the alfalfa.

Conclusions

Soil and tissue tests that can characterize degrees of N excess during corn production have immediate utility for demonstrating the economic and environmental benefits of N fertilizer adjustments. We found that most fields surveyed in this Iowa study had much more nitrate-N than needed to attain maximum yields of corn. Farmers could have increased the profitability of corn production and substantially reduced the potential for groundwater contamination if they had adjusted rates of commercial fertilizer application to account for N supplied by the previous alfalfa crops.

REFERENCES CITED

1. Binford, G. D., A. M. Blackmer, and N. M. El-Hout. 1990. *Tissue test for excess nitrogen during corn production.* Agron. J. 82: 124-129.
2. Blackmer, A. M. 1987. *Losses and transport of nitrogen from soils.* In Frank M. D'Itri and Lois G. Wolfson [eds.] *Rural Groundwater Contamination.* Lewis Publishers, Inc., Chelsea, Mich. pp. 85-103.
3. Blackmer, A. M., D. Pottker, M. E. Cerrato, and J. Webb. 1989. *Correlations between soil nitrate concentrations in late spring* and *corn yields in Iowa.* J. Production Agr. 2:103-109.
4. DeVault, G. 1982. *The never-never land of N.* New Farm 4(1): 29-41.
5. Fox, R. H., and W. P. Piekielek. 1984. *Relationships among anaerobically mineralized nitrogen, chemical indexes, and nitrogen availability to corn.* Soil Sci. Soc. Am. J. 48: 1087-1090.
6. Hallberg, G. R. 1986. *From hoes to herbicides: Agriclture and groundwater quality.* J. Soil and Water Cons. 41(6): 357-364.
7. Kaap, J. D. 1986. *Implementing best management practices to reduce nitrate levels in northeast Iowa groundwater.* In Proc., Agr. Impacts on Ground Water Conf. Nat. Water Well Assoc., Dublin, Ohio. pp. 412-427.
8. Keeney, D. R. 1986. *Sources of nitrate to ground water.* CRC Crit. Rev. Environ. Control 16(3): 257-303.
9. Libra, R. D., G. R. Hallberg, B. E. Hoyer, and L. G. Johnson. 1986. *Agricultural impacts on ground water quality: The Big Spring Basin study, Iowa.* In Proc., Agr. Impacts on Ground Water Conf. Nat. Water Well Assoc., Dublin, Ohio. pp. 253-273.
10. Magdoff, F. R., D. Ross, and J. Amadon. 1984. *A soil test for nitrogen availability to corn.* Soil Sci. Soc. Am. J. 48: 1301-1304.
11. National Research Council. 1978. *Nitrates: An environmental assessment.* Nat. Acad. Sci., Washington, D.C. 723 pp.
12. Padgitt, Steven. 1986. *Agriculture and ground water quality as a social issue: Assessing farming practices and potential for change.* In Proc., Agr. Impacts on Ground Water Conf. Nat. Water Well Assoc., Dublin, Ohio. pp. 134-144.
13. Spector, P. C., J. H. Goodnight, J. P. Sall, and W. S. Sarle. 1985. *The GLM procedure.* In *SAS User's Guide: Statistics, 1985.* SAS Inst., Inc., Cary, N. Car. pp. 433-506. □

Soil physical properties after 100 years of continuous cultivation

S. H. Anderson, C. J. Gantzer, and J. R. Brown

ABSTRACT: A study was conducted to evaluate the effects of 100 years of continuous soil and crop management on soil physical properties at Sanborn Field, University of Missouri. Undisturbed soil cores were used to evaluate bulk density, saturated hydraulic conductivity, water retention, and pore-size distributions. Results indicate that annual additions of manure decreased bulk density by an average of 0.12 g cm^{-3} compared to unfertilized treatments. Saturated hydraulic conductivity was increased by about nine times with annual additions of 13.5 t ha^{-1} (6 tons/acre) of manure. Implications are that soil and crop management have only subtle effects on bulk density and pore-size distribution for this soil. However, annual additions of manure increased hydraulic conductivity, which may reduce runoff and the potential for soil erosion.

CONCERNS have arisen in recent years about the economic and environmental sustainability of intensive row-crop agriculture in the United States (*28*). The profitability of intensive row-crop systems has declined during the past decade, possibly because of a decline in commodity prices and an increase in machinery, fuel, fertilizer, and pesticide costs (*28*). Public concern about surface water and groundwater contamination (*1, 15*) has pointed out the need to improve current row-crop management techniques. Recent interest has focussed on low-input or sustainable agricultural techniques to minimize the environmental consequences of row-crop production. Historically, the Amish have used a type of low-input agriculture (*18*). Their practices have included rotations with legumes and annual additions of animal manure.

Although different types of sustainable agricultural systems, such as use of rotations and annual additions of animal manure, have been suggested, little work has been published that quantifies how long-term use of such practices may alter soil physical properties and thus influence potential environmental impacts. A desired environmental effect of these types of management may be to reduce stormwater runoff and soil erosion through increased water infiltration. Incorporation of animal manure into the soil may have beneficial effects on soil physical properties that may increase infiltration rates. Manure incorporation has been shown to increase soil aggregation (*9, 13*), aggregate stability (*8, 31*), infiltration (*6, 18, 31*), and water-holding capacity (*13, 14*). In addition, manure incorporation has been shown to decrease bulk density (*18, 20*) and to increase a soil's resistance to compaction (*11*). One reason for the improvement in soil tilth is an increase in biological activity because of manure additions (*5, 8*).

Although some studies have quantified the effects of manure on soil physical properties, most have only examined the effects of manuring for a short time. Researchers at Rothamsted, England (*8*), and Sanborn Field at the University of Missouri-Columbia (*2, 29, 31*) have maintained experimental field plots that may be used to evaluate the effects of annual additions of manure for long time periods (100 years). Although Sanborn Field has been maintained under continuous cropping, it has only had limited characterization of soil physical properties during its 100-year history.

Our objective was to evaluate the effects of 100 years of soil fertility management for continuous cropping systems of wheat (*Triticum aestivum* L.); corn (*Zea mays* L.); timothy (*Phleum pratense* L.); and a 3-year, corn-wheat-red clover (*Trifolium pratense* L.) rotation on soil tilth, an indicator of possible environmental consequences of changing soil fertility management. The soil physical properties studied were bulk density, saturated hydraulic conductivity, soil water retention, and pore-size distribution.

Study methods

Sanborn Field is located on the University of Missouri campus at Columbia. The individual field plots have been under various continuous soil and crop management practices since 1888. The soil within the study area is a Mexico silt loam (fine, montmorillonitic, mesic Udollic Ochraqualf), which

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is representative of most of the gently rolling, more erodible soils of the Midwest claypan area, an area of about 4 million ha (9.9 million acres) within Missouri, Illinois, and Kansas (*19*).

We selected the following rotations for study: continuous wheat, continuous corn, continuous timothy, and a corn-wheat-red clover rotation. The soil fertility management treatments included annual fertilization with inorganic fertilizers, according to the Missouri soil test recommendations (*4*); annual addition of 13.5 t ha^{-1} (6 tons/acres) of barnyard manure; and no fertility added (unfertilized). Table 1 shows the soil and crop management history of the selected plots. Details of the management history of all plots have been described by other researchers (*29*).

Plots used in this study were selected from those that had been managed with constant treatment with only minor alterations since 1888. Initially, all plots had plant residues removed each year. However, this practice was discontinued recently. Since the 1970s, only continuous corn plots have had residues removed. Normal tillage for the plots is fall plowing.

We selected the following cropping treatments to compare the effects of annual fertilization or manuring with unfertilized treatments: continuous wheat (plots 2, 9, 10); continuous corn (plots 6, 17, 18); continuous timothy (plots 22, 23, 30); and a 3-year corn-wheat-red clover rotation (plots 25, 26, 27), referred to as the 3-year rotation. The rotation plots were planted to wheat in the fall of 1988. Table 1 shows changes from the original soil and crop management during the 100-year history.

Table 2 provides soil textural data for the surface horizon in each plot. These data were obtained using the pipette technique (*12*) on soil material taken for the 100-year characterization of the plots on Sanborn Field (*16*). The most notable feature in the data is that the plots with the corn treatment had much higher clay contents compared to the other plots. This was primarily because of topsoil erosion and the subsequent mixing of higher clay content material from the subsoil with the remaining topsoil (*10*).

Table 2 also shows soil organic matter data measured using a dry combustion furnace (*26*) and pH data measured in 0.01M $CaCl_2$ solution (*25*).

On March 14, 1989, we removed four, 76-mm-diameter × 76-mm-long undisturbed soil cores at soil depths of 25 to 100 mm (1 to 4 inches) using a Uhland sampler from each of the 12 selected plots. The soil cores, which were housed in aluminum rings, were taken using the core sampling method (*3*). The cores were trimmed and transported to the laboratory. We determined the soil water characteristic for each core at soil water potentials of 0.0, −0.4, −1.0, −2.5, −5.0, −10.0, −15.0, −20.0, −25.0, −30.0, and −40.0 kPa (*21*). After the cores were removed from pressure cells, they were weighed and slowly resaturated from the bottom over 48 hours. We then meaured saturated hydraulic conductivity using a constant-head permeameter (*22*). Soil cores were oven-dried and weighed to allow calculation of bulk density subsequent to measurement of the saturated hydraulic conductivity. We estimated pore-size distribution from the water retention data (*7*). The equivalent pore radius of the smallest drained pore neck was estimated using the following relation:

$$r = -2\,\sigma \cos\theta / (\varrho\, g\, h) \qquad [1]$$

where r is the equivalent pore radius, σ is the surface tension of water, θ is the contact angle, ϱ is the density of water, g is the gravitational acceleration, and h is the soil water pressure head.

We used pore-size classes (*23*) to categorize pore size macropores, >500 μm radius; mesopores, 5-500 μm radius; and micropores, < 5-μm radius. Mesopores

Table 1. Cropping and management history of Sanborn Field plots selected for the study.

Plot Number	Culture	Years	Soil Treatment
2	Wheat	1888-1949	Chemicals to replace harvest
		1950-1988	Fertilized by soil test
9	Wheat	1888-1988	Unfertilized
10	Wheat	1888-1988	Manured, 13.5 t ha^{-1}
6	Red clover	1888-1913	Manured, 13.5 t ha^{-1}
	Cowpeas	1914-1927	Manured, 6.7 t ha^{-1}
	4-year rotation	1928-1939	Fertilized
	C-3 grasses	1940-1949	Fertilized
	Corn	1950-1988	Fertilized by soil test
17	Corn	1888-1988	Unfertilized
18	Corn	1888-1988	Manured, 13.5 t ha^{-1}
22	Timothy	1888-1988	Manured, 13.5 t ha^{-1}
23	Timothy	1888-1988	Unfertilized
30	Wheat	1888-1913	Manured, 13.5 t ha^{-1}
	Wheat	1914-1927	Nitrogen, 11 kg ha^{-1}
	Wheat	1928-1939	Nitrogen, 23 kg ha^{-1}
	Wheat/lespedeza	1940-1949	Limed by soil test; phosphorus, 19 kg ha^{-1}
	Timothy	1950-1988	Fertilized by soil test
25	3-year rotation	1888-1939	Manured, 13.5 t ha^{-1}
		1940-1949	Manured 11.2 t ha^{-1} before corn only
		1950-1988	Manured, 13.5 t ha^{-1}; nitrogen, 112 kg ha^{-1} before corn and 37 kg ha^{-1} before wheat
26	3-year rotation	1888-1913	Manured, 13.5 t ha^{-1}
		1914-1927	Manured, 20.2 t ha^{-1} before corn only
		1928-1949	Limed by soil test; phosphorus 16 kg ha^{-1} before corn and wheat only
		1950-1988	Fertilized by soil test
27	3-year rotation	1888-1988	Unfertilized

Table 2. Average silt content, clay content, organic matter, and pH for the surface horizon of selected plots of Sanborn Field.

Crop and Soil Management	Plot Number	Silt Content	Clay Content	Organic Matter	pH
		%			
Wheat					
Unfertilized	9	72.0	21.8	1.45	4.5
Fertilized	2	59.6	26.6	2.18	4.8
Manured	10	73.5	20.5	2.70	5.7
Corn					
Unfertilized	17	66.7	26.7	0.90	4.5
Fertilized	6	68.1	21.5	1.90	5.4
Manured	18	62.5	30.0	2.48	6.3
Timothy					
Unfertilized	23	76.9	16.7	2.45	5.0
Fertilized	30	70.9	19.9	2.38	5.6
Manured	22	76.9	16.7	4.03	6.2
Rotation					
Unfertilized	27	80.0	14.8	2.05	5.2
Fertilized	26	76.3	16.1	2.50	5.0
Manured	25	75.3	17.1	3.23	5.7

were further classified (*17, 27*) into coarse mesopores (25-500 μm radius) and fine mesopores (5-25 μm radius).

Results and discussion

Bulk density. Table 3 shows the means and coefficients of variation for bulk density measured on cores removed in 1989. Bulk density varied from 1.13 g cm^{-3} in the manured corn plot to 1.45 g cm^{-3} in the unfertilized wheat plot. The coefficients of variation for the plots were all less than 10%, which is expected for bulk density measurements (*30*). We found that the lowest bulk densities for each cropping treatment were in the manured treatments. This was expected because annual additions of manure will increase soil organic matter and improve soil structure. The highest bulk densities for each cropping treatment occurred in the unfertilized treatments, except in the timothy plots.

Only two contrasts could be made using individual plots for replication. The "fertilized vs. others" (others included manured and unfertilized) contrast was not significant at the 0.10 level for bulk density, while the "manured vs. unfertilized" contrast was significant at the 0.10 level (Table 4). The effect of 100 years of annual manure applications resulted in an average decrease of 0.12 g cm^{-3} in bulk density. Although we found differences in bulk density between treatments, the differences probably did not restrict root growth. The lower bulk densities in the manured treatments were due to higher concentrations of organic matter (Table 2). The higher organic matter content indicates that slightly better soil tilth may occur because organic matter creates conditions favoring better soil structure and less potential soil crusting.

Saturated hydraulic conductivity. Table 3 shows saturated hydraulic conductivity means. The hydraulic conductivity varied from 0.001 m hr^{-1} in the unfertilized wheat plot to 1.089 m hr^{-1} in the manured corn plot. The coefficients of variations of the conductivity for the plots varied from 32% to 125%, which are similar to values obtained by other researchers (*30*). The highest hydraulic conductivity values occurred in the manured plots for all cropping treatments. The lowest hydraulic conductivity values were in the unfertilized plots, except for the timothy treatment. The "fertilized vs. others" contrast was not significant at the 0.10 level for hydraulic conductivity, while the "manured vs. unfertilized" contrast was significant at the 0.01 level (Table 4). Although only small differences existed in bulk density between manured and unfertilized plots, there were large differences in hydraulic conductivity.

Table 3. Means and coefficients of variation for bulk density and saturated hydraulic conductivity measured in 1989 in selected plots from Sanborn Field.

Crop and Soil Management	Bulk Density		Saturated Hydraulic Conductivity	
	Mean ($g\ cm^{-3}$)	Coefficient of Variation (%)	Mean ($m\ hr^{-1}$)	Coefficient of Variation (%)
Wheat				
Unfertilized	1.45	3.0	0.001	104.3
Fertilized	1.25	9.6	0.303	125.5
Manured	1.15	1.8	0.750	52.2
Corn				
Unfertilized	1.20	8.1	0.058	67.0
Fertilized	1.13	2.6	0.119	75.3
Manured	1.13	4.5	1.089	53.2
Timothy				
Unfertilized	1.24	1.8	0.262	69.5
Fertilized	1.34	2.5	0.188	82.2
Manured	1.18	0.5	1.037	56.3
Rotation				
Unfertilized	1.32	1.4	0.004	31.7
Fertilized	1.28	2.5	0.005	38.6
Manured	1.27	1.7	0.058	73.8

Table 4. Significance levels for single-degree-of-freedom contrasts for physical properties measured in 1989 in selected plots of Sanborn Field.

Physical Property	Effect*	Significance Level
Bulk density	Fertilized vs. others	NS
	Manured vs. unfertilized	0.10
Hydraulic conductivity	Fertilized vs. others	NS
	Manured vs. unfertilized	0.01
Water content (0.0kPa)	Fertilized vs. others	NS
	Manured vs. unfertilized	0.10
Water content (-0.4 kPa)	Fertilized vs others	NS
	Manured vs. unfertilized	0.05
Fine mesopore fraction (5 to 25 μm radius)	Fertilized vs. others	NS
	Manured vs. unfertilized	0.10

*Only those effects significant at the 0.10 level are illustrated.

Annual additions of manure for 100 years resulted in an average increase in saturated hydraulic conductivity of about nine times. We speculate that these annual manure additions increased biological activity, which altered soil structure, which in turn increased saturated hydraulic conductivity. Figure 1 illustrates the large correlation (r=0.95) between log-transformed conductivity and log-transformed number of pores greater than 1 mm in diameter. Pores were counted in the soil cores immediately after we determined saturated hydraulic conductivity. These pores probably were created by earthworms (*Lumbricus* sp.) because qualitative estimates of earthworm populations encountered during core sampling in the plots were correlated with the number of pores greater than 1 mm in diameter measured in the cores. Because saturated hydraulic conductivity was higher in manured plots, infiltration will be higher during many periods of the year for these treatments. Implications are that greater infiltration, less runoff, less soil erosion, but greater movement of nutrients through the soil profile could occur in plots having higher saturated conductivities. This will depend on the location of soil nutrients in relation to water moving through these macropores.

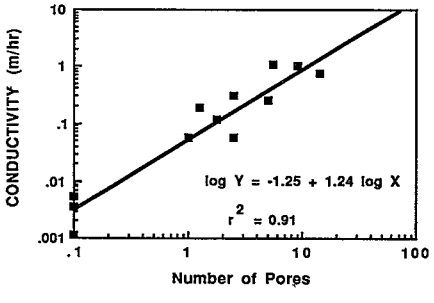

Figure 1. Mean saturated hydraulic conductivity as a function of the mean number of pores greater than 1 mm in diameter, measured in soil cores taken from the 25- to 100-mm depth in 1989 from Sanborn Field.

Water retention. Figure 2 shows water retention curves influenced by soil and crop management. Except for the corn treatments, the manured plots had the highest water content at saturation. We attributed this to the slightly lower bulk densities and higher organic matter levels that were present in the manured plots. The "fertilized vs. others" contrast was not significant at the 0.10 level for any part of the curve. However, the "manured vs. unfertilized"

contrast was significant at the 0.10 level for water contents at saturation and at −0.4 kPa. This may be important because use of manure can improve the water-holding capacity of the soil. However, our data showed no significant increase in water-holding capacity of the surface soil due to annual manure additions over 100 years.

Pore-size distribution. Figure 3 shows the relative proportions of pores divided into macropores, coarse mesopores, fine mesopores, and micropores, as influenced by soil management and cropping system. In general, there appeared to be a 20% greater proportion of macropores and coarse mesopores in the manured plots relative to the unfertilized plots. This effect was most striking in the wheat treatment. The "fertilized vs. others" contrast was not significant at the 0.10 level for any of the pore-size classes. However, the "manured vs. unfertilized" contrast was significant at the 0.10 level for the fine mesopores, with the unfertilized plots having a greater proportion of fine mesopores than the manured plots. Although there appeared to be a greater volume of large pores in some of the manured plots compared to the unfertilized plots, the effect was not consistent across all cropping treatments.

The primary benefit of the increase in coarse mesopores (25-500 μm radius) and the decrease in fine mesopores (5-25 μm radius) is a potential improvement in soil aeration, resulting in an improved medium for root growth and proliferation. Thus, the use of manure can improve the soil pore-size distribution by increasing the percentage of larger pores compared to unfertilized soil. However, no great differences in pore-size distribution occurred when inorganic fertilizers were added compared to manure for the soil used in this study.

Implications for sustainable agriculture. Soil physical properties are indicators of the environmental impact of soil and crop management systems. Our study suggests that the soil fertility treatment that had the highest hydraulic conductivity was annual additions of manure; the treatment with the lowest hydraulic conductivity was the unfertilized treatment. Although use of inorganic fertilizers did not directly add as much organic matter to the soil, its beneficial effects in promoting better plant growth and, thus, more residue caused the fertilized treatment to not be significantly different from that of manuring for the soil properties monitored. Research at Rothamsted, England, found that 70 annual additions of manure at rates similar to those in this experiment had no measureable effect on soil aggregate stability (*8*).

The one soil property that was significantly affected by annual additions of manure was saturated hydraulic conductivity. A possible reason for the higher hydraulic conductivity in the manured plots is that more earthworms were present because of more palatable organic matter for the worms to consume. One possible drawback to higher saturated hydraulic conductivity at the surface is the possibility of enhanced leaching of plant nutrients to groundwater. Groundwater quality for this type of soil (claypan) probably will not be significantly impacted because the high clay content of the subsoil impedes deep leaching of nutrients (*19, 24*). Denitrification also is enhanced during the winter and spring months in these soils because they are somewhat poorly or poorly drained.

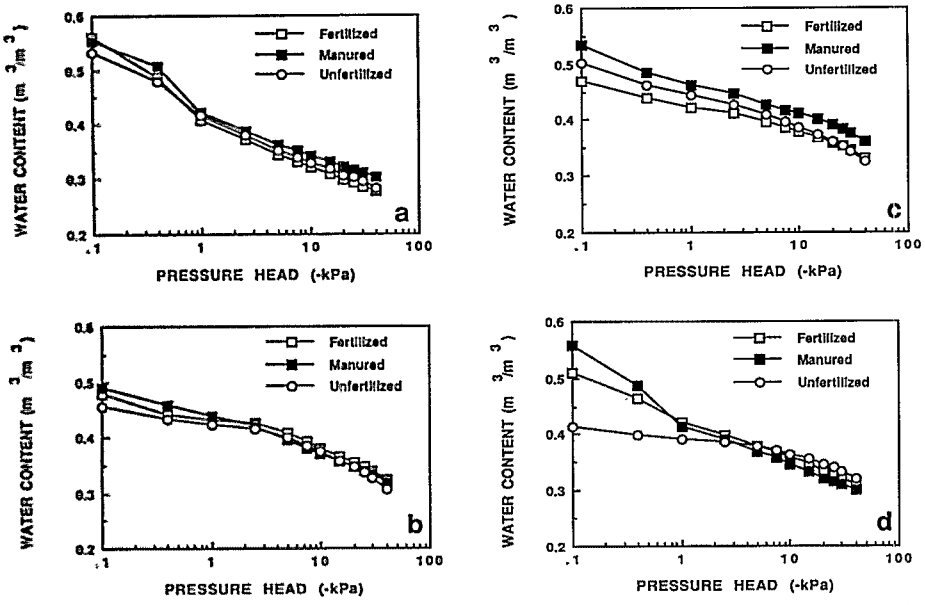

Figure 2. Water retention curves as affected by soil and crop management treatments measured in soil cores taken in the 25- to 100-mm depth from Sanborn Field from the following selected plots: (a) continuous corn, (b) corn-wheat-red clover rotation, (c) continuous timothy, and (d) continuous wheat.

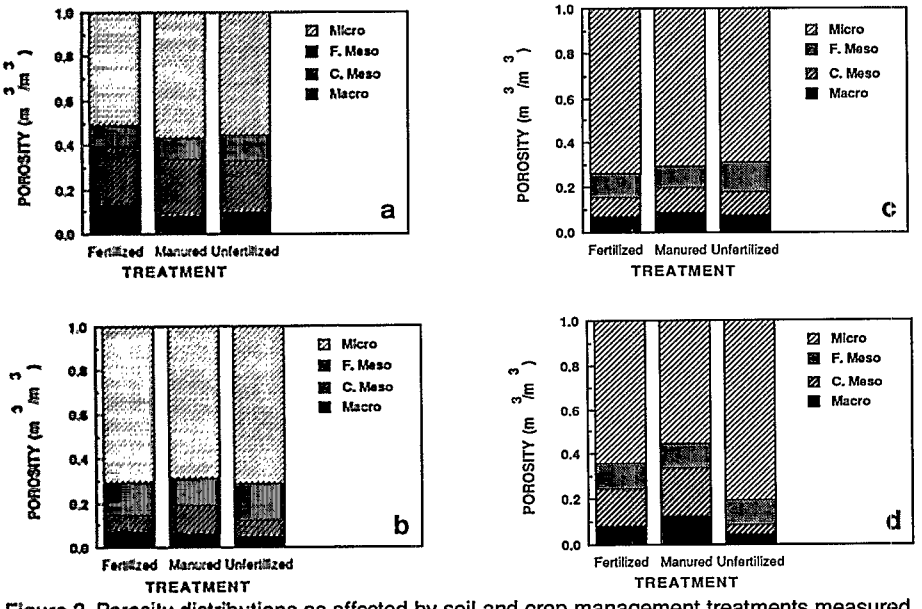

Figure 3. Porosity distributions as affected by soil and crop management treatments measured in soil cores taken in the 25- to 100-mm depth from Sanborn Field from the following selected plots: (a) continuous corn, (b) corn-wheat-red clover rotation, (c) continuous timothy, and (d) continuous wheat. Porosity distributions were obtained by the following pore-size classifications: micropores, less than 5 μm; fine mesopores, 5-25 μm; coarse mesopores, 25-500 μm; and macropores, greater than 500 μm in radius.

REFERENCES CITED

1. Baker, D. B. 1985. *Regional water quality impacts of intensive row-crop agriculture: Lake*

Erie Basin case study. J. Soil and Water Cons. 40: 125-132.
2. Balesdent, J., G. H. Wagner, and A. Mariotti. 1988. *Soil organic matter turnover in long-term field experiments as revealed by carbon-13 natural abundance.* Soil Sci. Soc. Am. J. 52: 118-124.
3. Blake, G. R., and K. H. Hartge. 1986. *Bulk density.* In A. Klute [ed]. *Methods of Soil Analysis, Part 1.* Am. Soc. Agron., Madison, Wisc. pp. 363-375.
4. Buchholz, D. D. 1983. *Soil test interpretations and recommendations handbook.* Dept. Agron. Univ. Mo., Columbia.
5. Converse, J. C., G. D. Bubenzer, and W. H. Paulson. 1976. *Nutrient losses in runoff from winter spread manure.* Trans., ASAE 19: 517-519.
6. Cross, O. E., and P. E. Fischbach. 1973. *Water intake rates on a silt loam soil with various manure application rates.* Trans., ASAE 16: 282-284.
7. Danielson, R. E., and P. L. Sutherland. 1986. *Porosity.* In A. Klute [ed]. *Methods of Soil Analysis, Part 1.* Am. Soc. Agron., Madison, Wisc. pp. 443-461.
8. Davies, D. B., and D. Payne. 1988. *Management of soil physical properties.* In A. Wild [ed]. *Russell's Soil Conditions and Plant Growth.* Longman, New York, N.Y. p. 437.
9. Elson, J. 1943. *A four-year study on the effects of crop, lime, manure, and fertilizer on macroaggregation of Dunmore silt loam.* Soil Sci. Soc. Am. Proc. 8: 87-90.
10. Gantzer, C. J., S. H. Anderson, and A. L. Thompson. 1989. *Estimating soil erosion after 100 years of cropping on Sanborn Field.* Spec. Rpt. Mo. Agr. Exp. Sta., Columbia.
11. Gaultney, L., G. W. Krutz, G. C. Steinhardt, and J. B. Liljedahl. 1982. *Effects of subsoil compaction on corn yields.* Trans., ASAE 25: 563-569.
12. Gee, G. W., and J. W. Bauder. 1986. *Particle-size analysis.* In A. Klute [ed.] *Methods of Soil Analysis. Part 1.* Am. Soc. Agron., Madison, Wisc., pp. 383-411.
13. Gregory, P. J. 1988. *Water and crop growth.* In A. Wild [ed]. *Russell's Soil Conditions and Plant Growth.* Longman, New York, N.Y. p. 357.
14. Hafez, A. R. 1974. *Comparative changes in soil physical properties induced by admixtures of manures from various domestic animals.* Soil Sci. 118: 53-59.
15. Hallberg, G. R. 1986. *From hoes to herbicides: Agriculture and groundwater quality.* J. Soil and Water Cons. 41: 357-364.
16. Hammer, R. D., and J. R. Brown. 1989. *One hundred years of Sanborn Field: Lessons for future long-term research.* Spec. Rpt. Mo. Agri. Exp. Sta., Columbia.
17. Hartge, K. H. 1978. *Einfuhrung in die Bodenphysik.* Ferdinand Enke Verlag, Stuttgart, W. Germany.
18. Jackson, M. 1988. *Amish agriculture and no-till: The hazards of applying the USLE to unusual farms.* J. Soil and Water Cons. 43: 483-496.
19. Jamison, V. C., D. D. Smith, and J. F. Thornton. 1968. *Soil and water research on a claypan soil.* Tech. Bull. 1379. Agr. Res. Serv., U.S. Dept. Agr., Washington, D.C.
20. Khaleel, R., K. R. Reddy, and M. R. Overcash. 1981. *Changes in soil physical properties due to organic waste applications: A review.* J. Environ. Qual. 10: 133-141.
21. Klute, A. 1986. *Water retention: Laboratory methods.* In A. Klute [ed]. *Methods of Soil Analysis, Part 1.* Am. Soc. Agron., Madison, Wisc. pp. 635-662.
22. Klute, A., and C. Dirksen. 1986. *Hydraulic conductivity and diffusivity: Laboratory methods.* In A. Klute (ed). *Methods of Soil Analysis, Part 1.* Am. Soc. Agron., Madison, Wisc. pp. 687-734.
23. Luxmoore, R. J. 1981. *Micro-, meso-, and macroporosity of soil.* Soil Sci. Soc. Am. J. 45: 671-672.
24. McGinty, K. S. 1989. *Tillage effects on soil physical properties and temporal variability of infiltration.* M.S. thesis. Univ. Mo., Columbia.
25. McLean, E. O. 1982. *Soil pH and lime requirement.* In A. L. Page et al. [ed.] *Methods of Soil Analysis, Part 2.* Am. Soc. Agron., Madison, Wisc. pp. 199-224.
26. Nelson, D. W., and L. E. Sommers. 1982. *Total carbon, organic carbon, and organic matter.* In A. L. Page et al. [ed.] *Methods of Soil Analysis, Part 2.* Am. Soc. Agron., Madison, Wisc. pp. 539-580.
27. Sekera, F. 1951. *Gesunder und kranker Boden.* 4. Aufl. Parey, Hamburg, W. Germany.
28. Stinner, B. R., and G. J. House. 1989. *The search for sustainable agroecosystems.* J. Soil and Water Cons. 44: 111-116.
29. Upchurch, W. J., R. J. Kinder, J. R. Brown, and G. H. Wagner. 1985. *Sanborn Field, historical perspective.* Bull. 1054. Mo. Agr. Exp. Sta., Columbia.
30. Warrick, A. W., and D. R. Nielsen. 1980. *Spatial variability of soil physical properties in the field.* In D. Hillel [ed.] *Applications of Soil Physics.* Academic Press, New York, N.Y. pp. 326-327.
31. Woodruff, C. M. 1939. *Variations in the state and stability of aggregation as a result of different methods of cropping.* Soil Sci. Soc. Am. Proc. 4: 13-18. □

Farming systems' influences on soil properties and crop yields

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*ABSTRACT: Systems that reduce off-farm agricultural inputs for crop production must retain soil productivity and farm profitability in order to be sustainable. This study determined the effects of the farming systems on soil physical properties and crop yields during the establishment stages of the systems. The three farming system treatments were alternate, conventional, and ridge-till. In the alternate system, no commercial fertilizers or pesticides and no moldboard plow were used. The four-year crop rotation in the alternate system was oats overseeded with alfalfa (*Avena sativa *L./*Medicago sativa *L.)-alfalfa-soybean (*Glycine max *L. merr)-corn (*Zea mays *L.). The crop rotations in the conventional and ridge-till systems were corn-soybean-spring wheat (*Triticum aestivum *L.), with primary tillage occuring after the conventional spring wheat. Soil water was limited in all systems because of drought in 1988. No one system consistently maintained soil water levels different from the others. Crop residue, especially in oats overseeded with alfalfa, kept soils cool and damp in the spring. Spring soil bulk density was reduced by tillage the previous fall, but differences were eliminated by mid-season. Soybean yield was generally greater in the alternate system than in the conventional or ridge-till systems. Corn grain yield was greater in the conventional and ridge-till systems than in the alternate system until drought stress reversed the rank. Conventional wheat consistently had higher yields than ridge-till wheat. Differences in soil physical properties were related to specific management practices or environmental influences, as opposed to being characteristic of a system, and alternate systems may have their greatest potential under drought stress.*

LOW-INPUT, sustainable agricultural systems are being examined in many midwestern land grant universities. South Dakota State University has been conducting farming systems research since 1984. Preliminary results indicate that alternate systems without commercial fertilizers or pesticides and without use of the moldboard plow can compete economically with conventional and ridge-till systems (*2*).

Tillage and crop rotation research has been abundant. Conservation tillage systems have been refined to meet compliance requirements while maintaining crop yields that are competitive with conventional systems (*4*). Rotations have been important in the success of these conservation tillage systems. (*5*). Recent concern about reducing agricultural chemical use and protecting groundwater quality has made low-input, sustainable agriculture an important area of research. The sustainability of a farming system relies heavily on sustained soil productivity.

This article presents data from a study with the specific objectives of comparing the influence of three farming systems on soil physical properties and crop yields.

Study methods

Field studies were established in 1985 at the Northeast research station near Watertown, South Dakota, on a Brookings silty clay loam (Pachic Udic Haploboroll). The long-term objectives are to determine the agronomic, economic, and environmental sustainability of three farming systems. This report discusses the analyses of soil properties and the yields achieved during the

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Table 1 Crop rotation and fall primary tillage in each system during 1986, 1987, and 1988.

System	Crop Rotation	Primary Tillage 1986	1987	1988
Alternate	Oat-alfalfa	None	None	None
	Alfalfa	Chisel	Chisel	Chisel
	Soybeans	None	None	None
	Corn	Disk	Disk	Disk
Conventional	Corn	None	Disk	Disk
	Soybeans	None	None	None
	Spring Wheat	Moldboard	Moldboard	Moldboard
Ridge	Corn	None	None	None
	Soybeans	None	None	None
	Spring Wheat	Fall-ridged	Chisel	Chisel

Table 2 Cultural practices for row crops in each system, 1986-1989.

Crop	System	Year	Planting Date	Seeding Rate (1,000 seeds ha^{-1})	Herbicide Rate (AI kg ha^{-1})		Hand Weeding (hrs ha^{-1})	N-P-K as Fertilizer (kg ha^{-1})
Corn	Alternate	1986	May 19	479	None		None	None
		1987	May 12	479	None		None	None
		1988	May 4	456	None		None	None
		1989	May 9	456	None		None	None
	Conventional	1986	May 14	479	Lasso II	1.2	None	112-0-0
		1987	May 6	479	Lasso II	1.2	None	41-0-0
		1988	May 4	456	Lasso II	1.2	None	84-34-0
		1989	May 9	456	Lasso II	1.2	None	None
	Ridge-till	1986	May 19	479	Lasso II	1.2	None	112-0-0
		1987	May 6	479	Banvel	0.3	None	41-0-0
					Lasso II	1.2	None	
		1988	May 4	456	Lasso II	1.2	None	118-34-0
		1989	May 9	456	Lasso II	1.2	None	None
Soybeans	Alternate	1986	May 28	370	None		2.8	None
		1987	May 15	370	None		0.0	None
		1988	May 10	370	None		2.6	None
		1989	May 16	370	None		5.2	None
	Conventional	1986	May 20	370	Treflan	0.8	2.6	None
		1987	May 14	370	Treflan	0.8	4.0	None
		1988	May 10	370	Treflan	0.8	3.0	None
		1989	May 16	370	Treflan	0.8	3.7	None
	Ridge-till	1986	May 19	370	Lasso II	1.2	3.3	None
					Blazer +	0.4		None
					Poast	0.3		None
		1987	May 13	370	Lasso II	1.2	3.4	None
					Blazer	0.4		None
		1988	May 10	370	Lasso II	1.2	2.8	None
		1989	May 16	370	Lasso II	1.2	4.7	None
					Poast + Crop oil	0.2		None

Table 3. Cultural practices for spring wheat and alfalfa in each system, 1986-1989.

Crop	System	Year	Planting Date	Seeding Rate (kg ha^{-1})	Herbicide Rate (AI kg ha^{-1})		N-P-K (kg ha^{-1})
Spring wheat	Conventional	1986	April 29	84	Hoelon	0.8	101-0-0
					MCPA	0.3	101-0-0
		1987	April 15	78	Hoelon +	0.8	86-0-0
					Buctril	0.3	86-0-0
		1988	April 11	78	Hoelon +	0.8	118-34-0
		1989	April 18	78	Hoelon +	0.8	129-22-0
					Buctril	0.3	129-22-0
	Ridge-till	1986	April 29	84	Hoelon	0.8	101-0-0
					MCPA	0.3	101-0-0
		1987	April 15	78	Hoelon +	0.8	86-0-0
					Buctril	0.3	86-0-0
		1988	April 11	78	Hoelon +	0.8	118-34-0
					Buctril	0.3	118-34-0
		1989	April 20	78	Hoelon +	0.8	129-22-0
					Buctril	0.3	129-22-0
Oat-alfalfa	Alternate	1986	April 23	54/11	None		37-35-160*
		1987	April 16	54/11	None		117-31-198
		1988	April 12	54/11	None		126-21-119
		1989	April 21	56/11	None		118-33-86
Alfalfa	Alternate	1986	NA	NA	None		None
		1987	NA	NA	None		None
		1988	NA	NA	None		None
		1989	NA	NA	None		None

*Fall application of feedlot manure at 4.5, 5.6, 6.0, and 6.2 t ha^{-1} in 1986, 1987, 1988, and 1989, respectively.

establishment years of the systems, compares crops within each system, and compares the effects of the systems on a particular crop.

Crops included in the systems were chosen to represent the dominant crops produced in northeastern South Dakota. The alternate system was similar to that used by alternative farmers in the area. The alternate system's rotation was oats overseeded with alfalfa (*Avena sativa* L./*Medicago sativa* L.)-alfalfa-soybeans (*Glycine max* L. merr.) -corn (*Zea mays* L.). In this four-year rotation, alfalfa was used to reduce weed problems, to interrupt disease and insect cycles, and to provide nutrients for subsequent crops. The stand was maintained for 1 year past the establishment year. Alfalfa stands, which are traditionally maintained 4-5 years as hay crops, can deplete soil moisture and increase perennial weeds, thus limiting yields of following crops. Also, older stands are more subject to foliar, root, and crown diseases; nematodes; and weevils and may be more difficult to incorporate without the use of the moldboard plow. Feedlot manure was applied in the fall to the oats-alfalfa treatment. Alfalfa forage was harvested three times each year. In most years alfalfa was incorporated by undercutting followed by chisel plowing. Alfalfa was followed by soybean rather than corn, which requires more water. Soybeans use less water than corn and are planted later so that soils can store early spring rainfall. The later planting also allows a later pre-plant tillage for weed control. Corn followed soybeans as the last crop in the rotation. In the alternate system no commercial fertilizers or pesticides were used. The cultural practices are summarized in tables 1, 2, and 3.

The conventional system had a crop rotation of corn-soybeans-spring wheat (*Triticum aestivum* L.). In the conventional system recommended rates of herbicides were used and soils were fertilized according to soil tests (Tables 2 and 3). Corn stubble was generally disked in the fall (Table 1), and a field cultivator and disk were used to incorporate herbicide prior to soybean planting. Soybean stubble was not tilled in the fall, but was disked prior to wheat planting. After harvest, conventional spring wheat plots were moldboard-plowed.

In the ridge-till system, the crop rotation was corn-soybeans-spring wheat. Recommended rates of fertilizer and herbicide were used. Corn plots were ridged at second cultivation (except in 1986 when wheat stubble was ridged in the fall). Soybean plots were planted on existing ridges, but not ridge-cultivated. Wheat following soybeans in the ridge-till system was then planted on nearly level ground. Wheat was seeded with

a hoe-drill. This ridge rotation was developed to accommodate farmers who wanted to use ridge-till as a soil conservation practice, but who had small grains in their rotation.

In each system all crops in the rotations were planted each year. Because the study was established in 1985, the longest rotation, the alternate system, was completed in 1988. In most years of the study all row crops in all systems were cultivated twice. In the alternate system, row crops were also rotary-hoed twice. Plot size was 311 m² (3,350 square feet) to allow for the use of field-scale equipment. Row crops were planted in 92-cm (36-inch) rows and small grains were drilled with 17.15-cm (6.75-inch) spacing. The design was a randomized complete block with four replications. Soil gravimetric water content and bulk density were measured in the top 15 cm (6 inches) of soil in April and July. Soil bulk density samples were taken with a Uhlen sampler. Soil temperatures (0-15 cm depth) were also recorded in April and July using a metal thermometer for point measurements in the row. Each fall, soil water content was measured gravimetrically at depths of 0-15, 15-60, and 60-120 cm (0-6, 6-24, and 24-48 inches). Seasonal rainfall and the deviation from the long-term average are given in table 4. Additional data collected included crop residue as a percentage of soil surface covered and crop yields. Data were analyzed with a general linear model program for PC-SAS (1985). Fisher's protected least significant difference (FLSD) was used to separate means.

Results

Soil water. In 1987, soil water (0-15 cm) declined as the season progressed and crop demands increased (Tables 5 and 6). In 1988, soil water dropped to critically low levels during drought conditions but increased with fall rainfall. Spring (5/19) soil water in 1989 was greater than soil water during the fall of 1988 (7/21), but decreased with crop removal and limited summer rainfall. The oats and alfalfa residue caught more snow than other treatments, and soil water levels in the springs of 1987 and 1989 were greater in alfalfa than other alternate crops (Table 5). By mid-July, the differences in soil water were no longer significant. In the conventional system, there was a general tendency for soybean-producing soils to have greater soil moisture than spring wheat-producing soils. Crop-related trends were not consistent for soil moisture levels in the ridge-till system.

Comparing systems within crops, soil water for spring wheat was greater in the conventional system than in the ridge-till system in only one situation. The 0-15 cm depth in the fall of 1988, when harvest was followed by rainfall, had higher soil water content when the spring wheat stubble was turned with a moldboard plow than when it was chisel-plowed (Table 6). This difference was not evident in the spring soil moisture level. Differences among systems for soybean-producing soils were not consistent throughout the season in 1987 and were not significant in 1988 or 1989. Consistent trends for differences due to the system used

Table 4. Growing season precipitation, 1986-1989.

	Precipitation by Year			
Month	1986	1987	1988	1989
	cm			
April	14.1	1.4	1.5	7.5
May	11.8	5.2	7.0	2.9
June	9.2	3.0	1.8	4.4
July	10.5	10.6	2.2	6.1
August	7.9	14.3	10.2	11.4
September	10.6	6.2	7.6	3.9
October	0.3	1.1	0.5	1.4
Total	64.5	41.8	30.8	37.6
Deviation*	+20.6	−2.1	−13.1	−6.3

*Deviation from 30-year average.

Table 5. Soil water (0-15 cm depth) in April and July as influenced by farming system.

			Soil Water by Date							
			1987		1988		1989		Average	
System	Residue*	Crop*	4/15	7/6	4/25	7/21	4/19	7/12	April	July
			%							
Alternate	CO	OA	24	21	18	7	21	11	21	12
	OA	AL	30	23	19	8	24	12	20	14
	AL	SB	25	21	18	8	22	15	18	15
	SB	CO	18	23	17	8	23	13	19	14
Conventional	SW	CO	21	25	18	6	22	14	24	15
	CO	SB	25	24	18	9	23	17	20	17
	SB	SW	20	20	20	7	21	13	20	14
Ridge-till	SW	CO	17	23	19	8	26	16	17	16
	CO	SB	17	21	17	9	24	15	21	15
	SB	SW	23	20	20	7	23	11	20	13
$FLSD_{.05}$			5.2	2.2	NS	1.4	2.2	2.1	NS	1.4

*CO = corn, OA = oats, AL = alfalfa, SB = soybeans, SW = spring wheat.

Table 6. Soil water content in the fall profile as influenced by farming system.

		Soil Water Content in Soil Profile by Year and Depth (cm)								
		1987			1988			Average		
System/Crop		0-15	15-60	60-120	0-15	15-60	60-120	0-15	15-60	60-120
		%								
Alternate	OA*	18	13	8	13	14	9	16	13	9
	AL	18	12	6	12	18	10	15	15	8
	SB	19	14	10	17	15	10	18	14	10
	CO	19	13	8	17	14	11	17	14	10
Conventional	CO	20	13	9	14	11	9	17	12	9
	SB	19	16	10	16	16	11	17	16	10
	SW	18	20	11	15	13	12	16	16	12
Ridge-till	CO	19	13	11	16	14	8	18	14	10
	SB	20	16	12	17	16	12	18	16	12
	SW	19	17	8	12	14	10	15	15	9
$FLSD_{.05}$		NS	2.4	2.7	2.8	3.5	NS	NS	NS	NS

*CO = corn, OA = oats, AL = alfalfa, SB = soybeans, SW = spring wheat.

Table 7. Effect of farming system on fall and spring soil surface residue cover.

			Residue Cover by Date					
	Fall	Spring	1987-1988		1988-1989		Average	
System	Residue*	Crop*	10/20	5/23	10/19	5/19	October	May
			%					
Alternate	OA	CO	98	99	99	100	98	99
	AL	OA	31	29	41	38	36	33
	SB	AL	66	42	46	43	56	42
	CO	SB	61	39	46	33	54	36
Conventional	CO	SW	66	49	27	23	47	36
	SB	CO	78	45	37	33	57	39
	SW	SB	26	12	15	6	21	9
Ridge-till	CO	SW	66	51	48	35	57	43
	SB	CO	69	48	61	54	65	51
	SW	SB	91	74	68	54	79	64
$FLSD_{.05}$			12.7	13.8	14.1	12.5	14.0	12.8

*CO = corn, OA = oats, AL = alfalfa, SB = soybeans, SW = spring wheat.

for corn production were not evident.

When soil water content was averaged across years, April values were not significantly different due to treatment (Table 5). By mid-July, soil water reflected crop use, and spring wheat nearing maturity had removed more water than the row crops. Spring wheat in the ridge-till system had less water in the 0-15 cm depth than conventional spring wheat. Fall soil water contents, when averaged over years, were not different due to treatment (Table 6).

Crop residue and soil temperature. Crop residue ranged from 100% of the soil surface covered in oats-alfalfa to 6% in plowed spring wheat stubble (Table 7). Using the chisel plow in spring wheat stubble left significantly more surface residue than using the moldboard plow. Ridging also maintained higher row-crop residues than the conventional treatments. Treatment differences averaged over 2 years remained significant.

Surface residue insulated the soil and decreased spring soil temperatures (Table 8). Oats-alfalfa residues kept April soil temperatures cooler than other crops. Spring wheat residue that had been moldboard-plowed allowed soils to warm rapidly in the spring of 1987 when there was no snow cover. In 1988, spring soil temperatures were measured later than in 1987 or 1989, and no differences were found. When averaged over years, only the oats-alfalfa residue soils were significantly oats-alfalfa cooler than other treatments. The oats-alfalfa residue itself, as well as its effectiveness in trapping snow, made it a good soil insulator.

Mid-July soil temperatures at the 0-15 cm depth reflected differences in soil water content. When averaged over years, soil temperatures were highest for small grain, followed by corn and then soybeans. This rank was reversed for soil water content.

Bulk density. Fall tillage was the primary influence on bulk density measured in the spring of 1987 (Table 9), and bulk densities were significantly lower in alternate/soybean, conventional/corn, and ridge-till/corn treatments that had been tilled the previous fall. Spring bulk density averaged over years was also significantly less in soils that had been fall-tilled. Significant differences in July bulk densities occurred in the summer of 1989 when conventional spring wheat plots were the most dense. This difference was not significant when averaged over years.

Grain yield. Corn grain yield was greater in the ridge-till and conventional systems than in the alternate system in 1986 and 1987, but was less than in the alternate system in 1988 during drought conditions (Table 10). Soybean yield in the alternate system was generally better than the ridge-till or conventional systems; the conventional system for spring wheat outyielded spring wheat grown in the ridge-till system. The 3-year average corn yields were not significantly different among systems, while soybean yields were highest for the alternate system and higher in the conventional system than in the ridge-till system. Spring wheat yields were higher in the conventional system than in the ridge-till system.

Table 8. Influence of farming system on soil temperature, in the row at 0-15 cm depth, in April and July.

			Soil Temperature by Date						
			1987			1988		Average	
System	Residue*	Crop*	4/15	7/6	4/23	4/19	7/12	April	July
			°C						
Alternate	CO	OA	17	25	20	9	31	15	28
	OA	AL	10	23	18	7	30	12	26
	AL	SB	16	23	20	8	28	15	26
	SB	CO	17	24	20	10	29	16	26
Conventional	SW	CO	20	24	19	7	29	15	26
	CO	SB	15	23	19	9	27	15	25
	SB	SW	16	25	20	9	32	16	28
Ridge-till	SW	CO	17	26	19	8	28	15	27
	CO	SB	16	23	19	10	27	15	25
	SB	SW	17	25	20	8	31	15	28
$FLSD_{.05}$			3.2	1.5	NS	1.5	1.4	1.6	1.3

*CO = corn, OA = oats, AL = alfalfa, SB = soybeans, SW = spring wheat.

Table 9. Soil bulk density in April and July as influenced by farming system.

			Soil Bulk Density* by Date							
			1987		1988		1989		Average	
System	Residue†	Crop†	4/15	7/6	4/25	7/21	4/19	7/12	April	July
			g/cc							
Alternate	CO	OA	1.5	1.3	1.4	1.2	1.3	1.1	1.4	1.2
	OA	AL	1.5	1.4	1.3	1.2	1.4	1.2	1.4	1.3
	AL	SB	1.1	1.2	1.3	1.2	1.3	1.1	1.2	1.2
	SB	CO	1.4	1.3	1.3	1.2	1.3	1.1	1.3	1.2
Conventional	SW	CO	1.1	1.3	1.3	1.2	1.2	1.1	1.2	1.2
	CO	SB	1.5	1.4	1.4	1.2	1.2	1.2	1.4	1.3
	SB	SW	1.6	1.2	1.4	1.2	1.3	1.3	1.4	1.2
Ridge-till	SW	CO	1.2	1.3	1.3	1.2	1.2	1.2	1.2	1.2
	CO	SB	1.3	1.4	1.3	1.2	1.3	1.1	1.3	1.2
	SB	SW	1.4	1.3	1.4	1.2	1.3	1.2	1.4	1.2
$FLSD_{.05}$			0.18	NS	NS	NS	NS	0.09	0.10	NS

*Sampled in the 0-15 cm soil depth.
†CO = corn, OA = oats, AL = alfalfa, SB = soybeans, SW = spring wheat.

Table 10. Grain yields as influenced by farming system.

		Grain Yields by Date			
Crop	System	1986	1987	1988	Average
		kg ha^{-1}			
Corn	Alternate	6,216	5,432	2,464	4,704
	Conventional	7,168	7,784	1,176	5,376
	Ridge-till	7,504	7,616	2,016	5,712
	$FLSD_{.05}$	285	784	694	NS
Soybeans	Alternate	1,980	2,123	720	1,608
	Conventional	1,860	2,083	600	1,514
	Ridge-till	1,680	1,920	600	1,400
	$FLSD_{.05}$	186	168	NS	110
Spring Wheat	Conventional	3,840	2,940	1,260	2,680
	Ridge-till	3,420	2,700	960	2,360
	$FLSD_{.05}$	228	192	156	147
Oats	Alternate	2,048	2,144	2,160	2,117
Alfalfa	Alternate	13.8*	9.97	6.47	10.08

*Alfalfa yields are reported in dry matter production (t ha^{-1}).

Discussion

Because this study was designed to compare systems, it is difficult to isolate effects. However, the soil parameters measured seemed to relate to a specific practice rather than to a total system. For example, the gravimetric soil water content in mid-July reflected crop use. Soil water content was

lower in small grains that were nearing maturity than it was in row crops, regardless of the system. Averaging over years did not indicate that one system retained more soil water than another.

The crop residue and its influence on soil temperature was dependent on crop and type of tillage used. Heavy residues left on the surface, as in the alternate oats-alfalfa treatment, kept soils cool and moist in the spring. Corn residue left in the ridge-till system had a similar effect. The 3-year spring soil temperature averages indicated that corn, for example, did not influence soil temperature differently in the alternate system that it did in the conventional system. By mid-July the main effect was no longer residue but crop growth. Crop water removal was inversely related to soil temperature. Soil bulk density was seldom different due to treatment, although in 1987 spring bulk densities were less in treatments preceded by fall tillage. Fall tillage also reduced 3-year average bulk densities.

Although the soil physical properties were not unique to a system, grain yields were different among systems. Soybean yields were generally greater for the alternate system than for the ridge-till and conventional systems. Soil physical properties measured did not explain the difference. Spring wheat yields were also greater in the conventional system than in the ridge-till system. A third example of system effects on yield was the increase in corn yields in the alternate system when crops were drought-stressed. This aspect of the alternate system is important to the sustainability of a system in an area where rainfall is limited. Economic analysis indicated that returns in the drought year were five times greater in the alternate system than in the conventional and ridge-till systems (*1*). Improved performance of alternative systems under drought stress was also reported by Sahs and Leosing (*7*).

The results of this study indicate that soil physical properties varied with specific practices or the environment rather than with the system and that the alternate system's greatest advantage may be in areas of limited rainfall. However, this study was conducted during the establishment phases of the systems, and it will be important to continue to monitor soil physical properties and crop yields through additional cycles of the rotation.

REFERENCES CITED

1. Dobbs, Thomas, and Clarence Mends. 1988. *Economic results in 1988 for northeast station alternative farming systems.* Annual Prog. Rpt. Plant Science pamphlet No. 1. S. Dak. State Univ., Brookings.
2. Dobbs, T. L., Lyle A. Weiss, and Mark G. Leddy. 1987. *Costs of production and net returns for alternative farming systems in northeastern South Dakota: 1986 and "normalized" situations.* Econ. Res. Rep. 87-5. S. Dak. State Univ., Brookings.
3. Ives, R. Morrison, and C. F. Shaykewich. 1987. *Effect of simulated soil erosion on wheat yields on the humid Canadian prairie.* J. Soil and Water Cons. 42(3): 205-208.
4. Frye, W. W., and R. L. Blevins. 1989. *Economically sustainable crop production with legume cover crops and conservation tillage.* J. Soil and Water Cons. 44(1): 57-60.
5. Langdale, G. W., and R. L. Wilson, Jr. 1987. *Intensive cropping sequences to sustain conservation tillage for erosion control.* J. Soil and Water Cons. 42(5): 352-355.
6. PC-SAS Institute, Inc. 1985. *SAS user's guide: Statistics.* Cary, N. Car.
7. Sahs, W. W., and G. Leosing. 1985. *Crop rotations and manure versus agricultural chemicals in dryland grain production.* J. Soil and Water Cons. 40(6): 511-516. □

Tillage and clover cover crop effects on grain sorghum yield and nitrogen uptake

R. G. Lemon, F. M. Hons, and V. A. Saladino

ABSTRACT: Winter annual legumes double-cropped with grain sorghum (Sorghum bicolor *L. Moench) can potentially provide nitrogen (N) for the sorghum and enhance long-term sustainability. A 4-year experiment was conducted near College Station, Texas, to evaluate conventional disk tillage, no-till, and green manuring for their potential in grain sorghum production. Annual clovers were used in combination with both no-till and green manure methods, which were compared to conventional disk tillage without clover. Fertilizer rates of 0 and 60 kg N ha^{-1} (54 pounds/acre) were used on all treatments. The green manure treatment with no added N produced higher grain yields than the similar conventional disk tillage treatment in 3 of 4 years and was statistically equal to conventional disk tillage receiving 60 kg N ha^{-1} (54 pounds/acre) in 3 of 4 years. Yields from no-till treatments without N fertilizer never matched those from conventional disk tillage treatments with fertilizer. Green manuring of clover prior to sorghum planting apparently better approximated clover N mineralization to sorghum demand, resulting in greater grain production. Grain sorghum no-till planted into clover surface mulch cannot be recommended because N availability was not synchronous with plant demand.*

LEGUME cover crops potentially can provide effective erosion control and biologically fixed nitrogen (N), enhancing long-term sustainability (*6*). More information is needed, however, about the effects that tillage systems have on the release of legume N to subsequent crops.

Much of the early research involving legumes was directed toward their use as green manures. In row-crop situations, legumes normally were rotated with the crop and plowed under, enabling a subsequent nonleguminous crop to benefit from the biologically fixed N. Kamprath and associates (*7*) and Fleming and associates (*3*) found that corn (*Zea mays* L.) yields increased substantially following a clover used as a green manure. Research has shown that legumes can function effectively as no-till surface mulches and N sources for succeeding crops (*2, 5, 9, 11*). However, reduced N mineralization associated with no-till legume residues remaining on the soil surface (*1*) and soil water depletion by preceding legumes may create difficulties for the crop immediately following the legume.

Most of the pioneering work dealing with legumes as supplemental N sources for no-till, spring-planted crops has been done in the midwestern and southeastern United States, where edaphic and climatic conditions favor such cropping systems. Little research has been reported for Texas or the Southwest concerning the adaptability of these types of production systems. As production costs continue to escalate and the date for conservation compliance approaches, the need for alternative cropping systems becomes increasingly important.

The objectives of our study were to determine the effects of tillage, annual clover, and N fertilization on grain sorghum (*Sorghum bicolor* L. Moench) yield and N uptake.

Study methods

We conducted field experiments in 1985 through 1988 at the Texas Agricultural Ex-

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periment Station Research Farm in Burleson County. The average annual precipitation for the area is 977 mm (38.5 inches); 444 mm (17.5 inches) normally occur during the sorghum-growing season, March through July. The soil in the study area is a Weswood silt loam (fine-silty, mixed, thermic Fluventic Ustochrept).

Tillage systems included conventional disk tillage without clover, no-till with clover, and green manure with clover treatments. Clover plots that were green-manured were disked twice and rebedded about 20 days prior to planting grain sorghum. Clover in no-till treatments was desiccated with paraquat (1,1'dimethyl-4,4'-bipyridinium ion) at the time clover was incorporated in green manure treatments. All treatments received preplant, subsurface-banded N as ammonium nitrate at rates of 0 and 60 kg N ha^{-1} (54 pounds/acre).

Treatments were arranged in a randomized complete block design with four replicates. Each plot was 12.2 m long (40 feet) and consisted of four rows 1 m (40 inches) apart. Treatments were repeated on the same plots over 4 years. During the first week in April of each year, grain sorghum was seeded at a rate to achieve 180,000 plants ha^{-1} (72,000 plants/acre). Grain was harvested in August each year.

Clover was sown with a standard grain drill in October of each year at a rate of 18 kg ha^{-1} (16 pounds/acre). Inoculant (*Rhizobium trifolii*) was applied as a seed treatment at planting. Dry matter yields of clover were determined in early March by hand-clipping random 1-m^2 (11.09-square-foot) quadrates prior to desiccation or tillage. At maturity, we hand-harvested 3 m (10 feet) of the middle two rows of each grain sorghum plot for grain and stover yields. Harvested panicles were threshed and grain yields adjusted to 14% moisture (U.S. grade 2). We removed stover at ground level from the harvested area for total stover dry matter estimation. All tissue samples (clover, grain, and stover) were ground to pass a 0.5 mm screen and digested in a sulfuric acid mixture (*10*). Nitrogen determinations were made using an autoanalyzer system.

The combined analysis of variance indicated a significant difference among years, and individual year analyses demonstrated significant treatment x N rate interactions for grain yield.

Results and discussion

The clover initially used in the study was Mt. Barker subterranean clover (*Trifolium subterraneum* L.), a fairly prostrate variety that sets seed below ground. The Mt. Barker variety, however, was not satisfactory for forage or N production, primarily because late maturity resulted in little forage growth by early March.

Table 1. Clover dry matter production, N construction, and total N content of aboveground tissue.

Year*	Dry Matter (kg ha^{-1})	N Concentration (%)	Total N (kg ha^{-1})
1985	860	3.23	27
1986	4,300	2.80	120
1987	5,110	2.63	134
1988	1,300	2.72	35

*Mt. Barker subterranean clover used in 1985; Bigbee berseem clover used in 1986, 1987, and 1988.

Subsequently, we used Bigbee berseem clover (*Trifolium alexandrinum* L.) for the remaining 3 years of the study. Bigbee berseem clover was better adapted to the calcareous soil and climate of the area; aboveground dry matter yields and the consequent N contained in the tissue were much greater than the subterranean variety (Table 1). We based clover yield on samples taken from the no-till and green manure treatments. We found no difference in clover production between tillage methods. Clover production in 1986 and 1987 was excellent. In 1988 clover stand establishment and forage growth were affected adversely by dry fall conditions, resulting in low clover yields.

Grain yields for all tillage treatments receiving 60 kg N ha^{-1} (54 pounds/acre) and the green manure treatment receiving no supplemental fertilizer N in 1985 were significantly greater than the conventional tillage and no-till treatments with no added fertilizer N (Figure 1a). The clover in the green manure treatment contributed considerably to final grain yield. In addition, the physical mixing of the tillage operation may have enhanced the mineralization of residual organic soil N.

The results suggested that incorporation of clover as a green manure promoted more rapid decomposition and mineralization of tissue N compared to the no-till treatments, where the clover acted as a surface mulch (*4*). The availability of N in the green manure treatment apparently was more synchronous with critical plant demands. On the other hand, the majority of N contributed by the surface mulch in the no-till treatment probably occurred during later stages of sorghum development. Vanderlip (*12*) showed that 70% of the total N present in grain sorghum at physiological maturity was accumulated prior to anthesis. Similarly, Locke and Hons (*8*) found that most fertilizer N accumulation occurred before anthesis in both conventional and no-till systems.

The no-till and green manure treatments with clover, but without fertilizer N, pro-

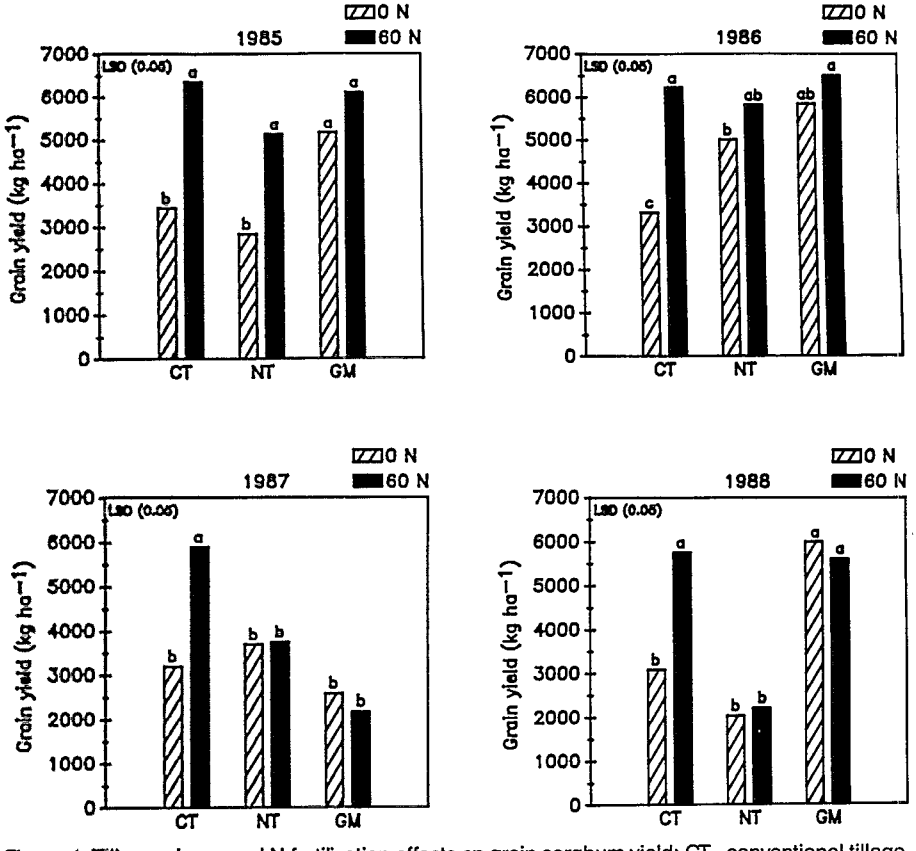

Figure 1. Tillage, clover, and N fertilization effects on grain sorghum yield; CT= conventional tillage, NT= no-tillage, GM= green manure.

duced significantly more grain than the conventionally tilled treatment without added N in 1986 (Figure 1b). The large forage and N production of bigbee berseem clover in 1986 contributed significantly toward sorghum grain yield in the no-till and green manure treatments receiving no fertilizer N (Table 1). The large amount of N in the above-ground clover tissue in 1986 apparently resulted in increased N availability, particularly in the no-till treatment. In 1985, however, little or no benefit was attained from the no-till surface mulch.

The 1987 sorghum-growing season was characterized by early spring moisture stress. We attributed major differences in yield between treatments to extremely dry soil conditions prior to and at planting, especially in the green manure treatments (Figure 1c). Green manure treatments were disked about 20 days prior to planting and rebedded. During the period from the first of March to the end of April, only 59 mm (2.32 inches) of rain fell, resulting in dry seedbed conditions. Similar conditions existed in the no-till treatments, resulting in poor stand establishment and yields in both tillage systems. Lack of significant rainfall immediately after planting also accentuated the stressful conditions imposed by the clover crop. Surface soil moisture was more adequate at planting in the conventional disk-tillage treatments with no clover, enabling the sorghum crop to establish and progress in a near normal pattern. Clover production in 1987 was 5,100 kg ha^{-1} (4,550 pounds/acre), resulting in 134 kg N ha^{-1} (120 pounds/acre) in the above-ground biomass (Table 1). Unfortunately, the early, dry conditions precluded any potential benefit to the grain sorghum crop.

The green manure treatment receiving no fertilizer N yielded significantly more sorghum grain than either of the similar no-till or conventional treatments in 1988 (Figure 1d). As in 1985 and 1986, greater grain yields and lack of response to applied N in the green manure treatment indicated that the clover supplied sufficient N for sorghum growth and grain yield. Although clover production was less in 1988 (Table 1), the substantial grain yields in the green manure treatments indicated a possible carryover of N from 1987. We attributed the depressed yields in the no-till treatments to delayed maturity caused by replanting. Replanting was necessary because of severe seedling disease; this resulted in flowering during peak sorghum midge (*Contarina sorghicola*) infestations. Consequently, neither clover nor added fertilizer N had much influence on no-till sorghum grain yield in 1988.

The interaction of tillage and N rate was not significant for total N removed in above-ground dry matter (stover+ grain). Total N in above-ground biomass averaged across N rates indicated that the general trend over the four years was for greater accumulation of total crop N in the green manure treatment (Figure 2). The response to green manuring was manifested not only in greater crop yields, but also in greater N removal.

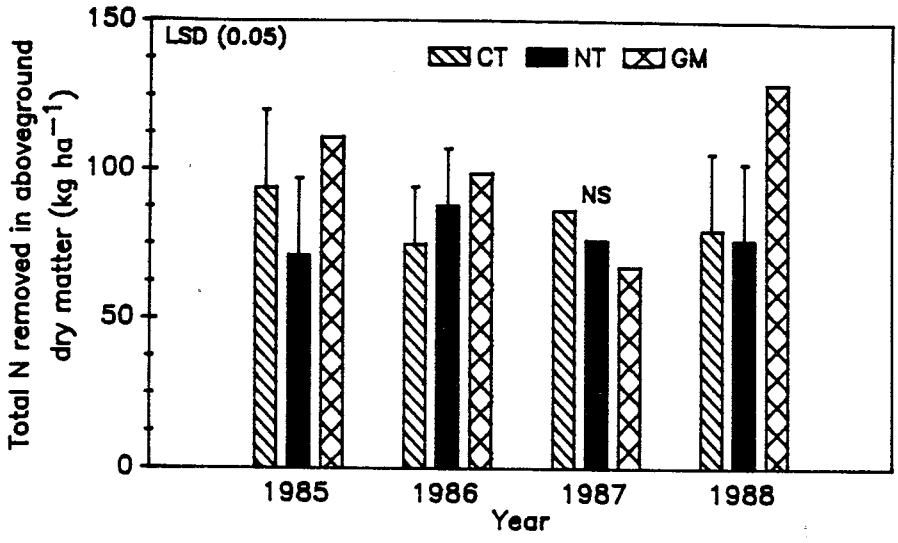

Figure 2. Tillage and clover effects on total N removed in above-ground dry matter. Least significant difference bars are for within-year comparisons only.

Conclusions

One problem with annual clover-grain sorghum tillage systems in the Southwest, is the early grain sorghum planting date (late March to early April) required to avoid sorghum midge damage. Early sorghum planting dictates that clover must attain appreciable forage growth prior to desiccation/tillage. Another problem with early sorghum planting is that clovers are not allowed to mature and set seed. Hence, clover must be replanted each year at an additional cost.

The green manure treatment with no added N produced significantly more grain than the similar conventional tillage treatment in 3 of 4 years and was statistically equal to conventional plots that received 60 kg N ha^{-1} (54 pounds/acre) in 3 of 4 years. No-till treatments receiving no N fertilizer produced greater grain yields than conventional plots with no added N in only 1 of 4 years, and no-till yields never equalled those on conventional plots with 60 kg N ha^{-1} (54 pounds/acre). The green manure system without supplemental N produced more grain than the similar no-till treatment in 2 of 4 years.

In our study environment, grain sorghum no-till planted into clover residue cannot be recommended because of apparent nonsynchrony between clover N mineralization and critical plant demand and severe soil water depletion by clover in 1 of 4 years. Green manuring of clover prior to sorghum planting apparently better matched clover N mineralization to sorghum demand, resulting in greater grain yields. Research over more years and/or modelling of the cropping system/climate may be necessary to determine the probability of soil water depletion by the clover crop that may adversely affect grain sorghum yield.

REFERENCES CITED

1. Doran, J. 1980. *Soil microbial and biochemical changes associated with reduced tillage.* Soil Sci. Soc. Am. J. 48: 790-794.
2. Ebelhar, S. A., W. W. Frye, and R. L. Blevins. 1984. *Nitrogen from legume cover crops for no-tillage corn.* Agron. J. 76: 51-55.
3. Fleming, A. A., J. E. Giddens, and E. R. Beaty. 1981. *Corn yields as related to legumes and inorganic nitrogen.* Crop Sci. 21: 977-980.
4. Groya, F. L., and C. C. Sheaffer. 1985. *Nitrogen from forage legumes: Harvest and tillage effects.* Agron. J. 77: 105-109.
5. Hargrove, W. L., 1986. *Winter legumes as a nitrogen source for no-till grain sorghum.* Agron. J. 78: 70-74.
6. Hargrove, W. L., and W. W. Frye. 1987. *The need for legume cover crops in conservation tillage production.* In J. F. Power [ed.] *The Role of Legumes in Conservation Tillage Systems.* Soil Cons. Soc. Am., Ankeny, Iowa. pp. 1-5.
7. Kamprath, E. J., W. V. Chandler, and B. A. Krantz. 1958. *Winter cover crops.* Tech. Bull. 129. N. Car. Agr. Exp. Sta., Raleigh.
8. Locke, M. A., and F. M. Hons. 1988. *Tillage effect on seasonal accumulation of labeled fertilizer nitrogen in sorghum.* Crop Sci. 28: 694-700.
9. Mitchell, W. H., and M. R. Teel. 1977. *Winter-annual cover crops for no-tillage corn production.* Agron. J. 69: 569-573.
10. Nelson, D. W., and L. E. Sommers. 1980. *Total nitrogen analysis of soil and plant tissues.* J. Assoc. Off. Anal. Chem. 63: 770-778.
11. Touchton, J. T., W. A. Gardner, W. L. Hargrove, and R. R. Duncan. 1982. *Reseeding crimson clover as a N source for no-tillage grain sorghum production.* Agron. J. 74: 283-287.
12. Vanderlip, R. L. 1979. *How a sorghum plant develops.* Coop. Ext. Serv. Circ. No. 1203. Kansas Agr. Exp. Sta., Manhattan. □

Spatial dimensions of farm input intensity: A pilot study

Abram Kaplan and John Steinhart

ABSTRACT: County-level agricultural input and demographic data from the Census of Agriculture were normalized and investigated through statistical and spatial analyses. State borders and state-level data were found to be poor guides for policy. Mapping of input criteria suggest strong regions of high- and low-input farm management practices, demonstrating that an empirical knowledge of where input-intensive farms exist will enhance one's ability to design and implement policies for low-input agriculture. Cluster analysis results reinforce the notion that conventional regions of agriculture that rely strictly on climate, geomorphology, and crop production are insufficient for assessing appropriate policy targets toward improved farm management. Four-state results offer encouragement for expanding an integrated, data-based perspective to the entire United States.

As low-input agriculture moves beyond anecdote and theory into the mainstream agriculture, many important questions arise. Among these are issues involving the tangle of present agricultural policy and the potential for initiatives to encourage sustainable agriculture.

First, what is meant by low-intensity or low-input farm management? Are all inputs to be considered? Because low is a comparative term, one might ask what "low" is being compared to. Some consensus on the definition of these concepts is clearly needed in the development of public policy.

Second, where are the areas of high-input and low-input farming, and what are their characteristics? This question is especially important for targeting new policy initiatives designed to affect input intensity and to evaluate the effectiveness of current policies.

Our research acknowledges both questions by attempting to identify the high- and low-input agricultural areas in four states. It responds to the first question by using a set of specifically identified farm production costs as a measure of input intensity and defines "low" relative to the mean of those input levels in the four-state area using a per-hectare normalized basis. The results deal with the second question more specifically. By illuminating both locational and management characteristics for a range of intensity in farm operating practices, these analyses offer a basis for the crucial aspects of policy development, design, and analysis.

The importance of the spatial component arises because of the differential patterns of agriculture in the nation. Both the academic and popular literature is besieged with various regions of agriculture, such as the corn and wheat belts of the Plains and Midwest and the central valley in California. The traditional system of policy "targeting"—identifying the appropriate audience to effect change—categorizes farmers by commodity production, financial need, or the assumption that all farms are essentially the same. The commodity credit program exemplifies the former two classes, while the land buy-back system underscores the latter.

Advances in the speed and capacity of microcomputers have made it possible to integrate a variety of measures of input use and to generate actual maps of those areas that have particularly intense farm management practices. We used a definition of intensity based on data from the Census of Agriculture and then used the subsequent data to delineate potential farm policy targets. If it is possible to portray coherent regions of high-input farming based on these indicators, then it may be possible to understand the characteristics of these areas and devise policies to affect input intensity. So the basic question we hope to answer is this: "Where are the high-input farming regions in the United States?"

The research presented here is from a demonstration project to test the methods and basic concepts involved in delineating input-based regions. We use data disaggregated to the county level as a compromise between farm-by-farm information, which is not available because of disclosure laws, and state- or national-level data, which are far too broad to be helpful in showing the disparity of farm management practices across the areas examined. Furthermore, as we contend that policies targeted on the basis of political boundaries, such as Census regions or states themselves, are likely to be inefficient, the use of state-level data would lead quickly to circular arguments.

As described below, this initial study uses data from four states: Wisconsin, Minnesota, California, and Oregon. These states were chosen on the basis of a number of criteria, including agricultural diversity, pairing of contiguous boundaries, and wide-ranging energy supply characteristics. The extent to which the results from this project prove viable will help determine whether an expansion to the entire nation is merited. While our research has included investigations of both input intensity and demo-

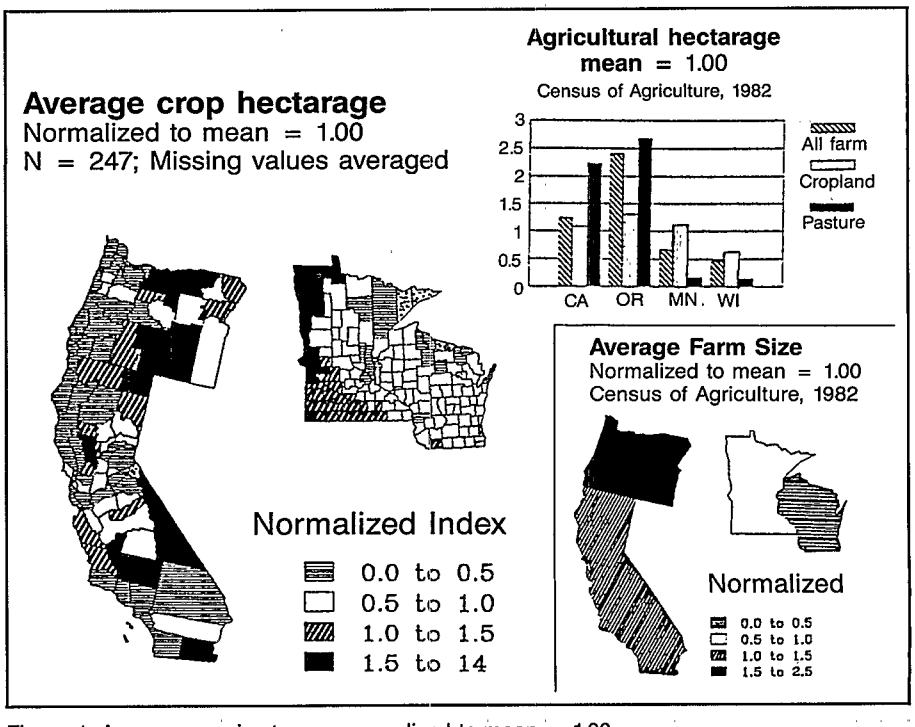

Figure 1. Average crop hectarage, normalized to mean = 1.00.

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graphic characteristics, this paper will describe only the former component.

Study methods

Agricultural regions often are defined in terms of climate, geomorphology, and crop production. These regions do not reveal the patterns of input intensity. The spatial arrangements we seek are certainly related to these characteristics, but they are not necessary corollaries. Simply because the soil is richer and the rainfall more consistent in southern Wisconsin does not require that farmers practice high-input farming there. In fact, one might find more intense management in the Sierra Nevadas, where the soil is poor, the climate harsh, and the slopes steep; there, it might be impossible to produce crops or manage livestock without the introduction of energy-intensive inputs.

Variables. The variables we examined represent the basis for understanding primary agricultural intensity: machinery and equipment, livestock feed, seeds, fertilizer, chemicals, labor, and a variety of energy inputs for on-farm management. By the same logic, we specifically ignored solar incidence, precipitation, groundwater levels, soil structure, and topography. All of these would no doubt prove important distinctions, but they do not represent the direct human impact on the environment or the likely context for input reduction policy initiatives.

The U.S. Census of Agriculture includes data that offer a rough surrogate for actual input intensity. Instead of presenting actual quantities consumed in fertilizer, energy, and the like, producers are asked to report the financial requirements for these production costs. Thus, for each county, we have the number of farms reporting each input cost and the total amount of money spent by all reporting farms for each input (Table 1).

Table 1. Mean and range of individual variables, U.S. Census of Agriculture, 1982.

Variable	Description/Units	Mean ($/ha)	Top Counties	Value ($/ha)	Bottom Counties	Value ($/ha)
STKPRPA	Expenses for livestock	137.34	Imperial, CA	3,419.32	Ashland, WI	8.33
			Fresno, CA	1,466.25	Wheeler, OR	5.04
			Tulare, CA	824.19	Wasco, OR	4.89
FDSTKPA	Expenses for feed for livestock	155.13	Imperial, CA	2,297.92	Gilliam, OR	5.36
			Riverside, CA	1,925.50	Grant, OR	3.85
			San Diego, CA	1,353.20	Wheeler, OR	1.63
SPBTSPA	Expenses for seeds, plants, trees, bulbs, etc.	34.91	Orange, CA	599.04	Wheeler, OR	0.78
			Ventura, CA	438.13	Trinity, CA	0.32
			Santa Cruz, CA	380.73	Mariposa, CA	0.22
CMFRTPA	Expenses for commercial fertilizer	47.99	Santa Cruz, CA	192.14	Inyo, Ca	1.04
			Imperial, CA	163.04	Mariposa, CA	0.77
			Riverside, CA	162.54	Trinity, CA	0.52
OTCHMPA	Expenses for other chemicals	33.36	Hood River, OR	318.41	Wheeler, OR	1.31
			Santa Cruz, CA	236.52	Grant, OR	0.94
			Ventura, CA	184.06	Trinity, CA	0.44
HRLBRPA	Expenses for hired labor	155.47	Ramsey, MN	2,140.35	Inyo, CA	8.40
			Santa Cruz, CA	2,074.03	Harney, OR	8.28
			San Mateo, CA	2,029.80	Gilliam, OR	7.93
CTWRKPA	Expenses for custom-work (rent, machine hire)	23.77	Riverside, CA	229.38	Inyo, CA	0.84
			Imperial, CA	134.87	Wheeler, OR	0.64
			Fresno, CA	131.48	Trinity, CA	0.47
GASLNPA	Expenses for gasoline	15.74	Hood River, OR	70.82	Grant, OR	1.75
			Santa Cruz, CA	70.23	Trinity, CA	1.73
			Ramsey, MN	70.18	Wheeler, OR	1.06
DIESLPA	Expenses for diesel fuel	20.81	Ramsey, MN	104.47	Mariposa, CA	0.82
			Hood River, OR	63.31	Wheeler, OR	0.79
			Milwaukee, WI	62.96	Tuolumne, CA	0.72
LPGASPA	Expenses for LP gas	18.90	Tillamook, OR	185.32	Wasco, OR	0.30
			Milwaukee, WI	182.38	Baker, OR	0.30
			Ramsey, MN	96.42	Gilliam, OR	0.12
ELECTPA	Expense for electricity	17.35	Santa Cruz, CA	118.34	Trinity, CA	1.01
			Riverside, CA	100.67	Grant, OR	0.79
			Ventura, CA	87.08	Wheeler, OR	0.59
OTHERPA	Expenses for other energy forms	4.57	Ventura, CA	43.51	Alameda, CA	0.00
			Washington, OR	39.09	Clatsop, OR	0.00
			Milwaukee, WI	25.74	Curry, OR	0.00
EQPVLPA	Equipment value	480.83	Hood River, OR	1,838.89	Grant, OR	30.54
			Ramsey, MN	1,257.52	Inyo, CA	29.21
			Santa Cruz, CA	1,166.10	Wheeler, OR	18.95
INTRSPA	Interest payments	120.80	Riverside, CA	581.84	Inyo, CA	10.82
			Santa Cruz, CA	429.18	Grant, OR	8.62
			Hood River, OR	414.90	Wheeler, OR	6.38

Data manipulation. We conducted a number of manipulations on the data to reduce obvious geographical biases and to indicate intensity levels instead of actual financial outlays. What we wanted to show was that farms in certain counties spend more on their inputs than other counties, not that farms in certain counties spend "X" dollars while other counties spend "Y" dollars. The absolute figures do not offer an estimate of intensity, but the relative values do.

If we were to divide the dollar amount by the number of farms reporting, we would have a fair estimate of per-farm input costs. But, as shown in figure 1, average farm size in the Midwest is much smaller than in the two western states; per farm estimates would unduly bias the results. Likewise, we avoided using total county figures because county sizes themselves tend to increase from East to West. By multiplying the number of the number of reporting farms by the average farm size per county for the generic inputs like electricity and machinery costs or by the average hectarage devoted to specific purposes for the variables clearly associated with that purpose, we could establish dollar-per-hectare values that would be far less susceptible to spatial autocorrelation difficulties.

It was also necessary to provide the basis for assessing relative intensity among these inputs instead of their absolute magnitude. Thus, each variable was normalized by the mean for the entire data set. (This has no biasing influence on the statistical analyses.) Thus, in the final matrix, a value of 1.00 for any given case represents an average input level. For example, where Fresno, California, is represented by the number 2.00 for commercial fertilizer costs, all we know is that farms in this county spend an average of twice as much on fertilizer per hectare than the mean for all counties in the data set. By that measure, Fresno might then be described as a high-input fertilizer county; those counties with values below 1.00, by this rough definition, would then qualify as low-input areas. We contend that geographic patterns that result from such transformed intensity figures are a great deal more enlightening than those arising from spatially autocorrelated data.

Methods. In addition to visual inspection of maps portraying the spatial patterns of each variable, a number of multivariate statistical methods could be applied to these issues as well. We have found the combination of two common tools to provide a powerful demonstration of the spatial potential for agricultural policy targeting: factor analysis (using orthogonal principal components, standard Varimax rotation, and Kaiser normalization procedures) and hierarchical cluster analysis (with squared Euclidean distance measures and average between-group linking for the actual clustering). The cluster analytics component is essentially a statistical corollary to the notion of overlays in a cartographic or geographic information system context. This is useful to identify the interrelationship of a variety of variables

across their basic unit, in this case, counties. All of these analyses were performed using SPSS/Pc+, version 3.0, on a 20MHz 80386-based microcomputer.

Missing values. The four states studied comprise 253 counties. Of these, six were dropped from the sample due to insufficient data: San Francisco, California (exclusively urban); Alpine, California (extremely mountainous and sparsely populated), Menominee, Wisconsin (Indian reservation); Vilas, Wisconsin (wilderness and recreation with little agriculture); and Lake and Cook counties, Minnesota (mining areas along with wilderness and recreation).

Three other counties were lacking farm hectarage data for use in the weighting scheme: Milwaukee, Wisconsin, and Mono and Inyo Counties, California. Hectarage estimates were made for these counties on the basis of prorated averages from total farm hectarage information for those counties. We are confident of the estimates for the two California cases because enough ancillary information was available for comparison; the merit of including Wisconsin's most urban county is less clear.

Additionally, a few counties lacked individual entries for specific input variables. The variable list itself was reduced to the set used for this study because of the missing data problem, but a few essential variables involved a small number (less than 5%) of missing values, which were estimated through an area-weighted averaging algorithm. A simple sensitivity analysis of these averaging techniques suggests that the matrix is not likely to be biased by filling a very small number of missing values in this manner, and the calculation of overall means for normalization is greatly facilitated. The final data set, then, includes 247 counties with no missing values.

Results and discussion

Figures 2 and 3 display a sample of the computer-generated maps of the essential input variables for normalized costs to farm operators. Each map uses an objective scale, which could be translated as follows: 0.0 to 0.5=very low intensity; 0.5 to 1.0=low intensity; 1.0 to 1.5=high intensity; and 1.5 to X=very high intensity, where X is the highest value listed. While each map is unique, there are a number of common spatial patterns worth noting; four of these are discussed. Other variables show similar phenomena.

The most obvious among these patterns is the repeated dominance of the Central Valley of California. In nearly every map, this area stands out as the most intense consumer of farm inputs, sometimes overwhelming the data set and thereby reducing almost all other counties to subaverage levels. The core of this region appears to be quite stable for these input variables, but the border counties seem to "wander" in and out of the very high-intensity category, depending on the variable. Among the sample maps, diesel fuel per hectare portrays the extreme of fewest counties included, while chemical costs displays the most. Interestingly, the eastern edge of the Central Valley is consistent in every map, while the southern and coastal counties shift. To some extent, this is endemic to the unit of analysis: we used county-wide averages, which are sure to produce generalized results.

A second common pattern in these maps is the suggestion of divergent management practices within the state of Oregon. While the location of the exact break is not clear, it appears that counties in the eastern two-thirds of the state group into a generally lower intensity category, while the western third follows more intensive management patterns. The area surrounding Portland in the northwest corner of the state also prevails as a very high-intensity region.

Moving to the Midwest, there is another spatial theme: the consistent reduction in intensity from south to north. Each input map displays three tiers, usually beginning in the southeastern area of Wisconsin with high-intensity input costs, then crossing the sample average in the middle of the two states to a very low-intensity region in the northern extremes of Wisconsin along with the northern third of Minnesota. In the case of both diesel fuel and chemical costs, there is a separation of the high-intensity region into the southeastern corner of Wisconsin and the southwestern corner of Minnesota. Other maps, such as equipment value, bridge these two areas, while labor costs remain very low in all but the southeastern and middle parts of Wisconsin.

Finally, across the majority of these maps is a pattern of urban versus rural farm practices. In hired labor, electricity, diesel fuel, and equipment value, the per-hectare costs are particularly high in the areas near Milwaukee, Green Bay, Minneapolis/St. Paul, Portland, San Francisco, and Los Angeles. One might expect these costs to be highest when farm size is restricted by develop-

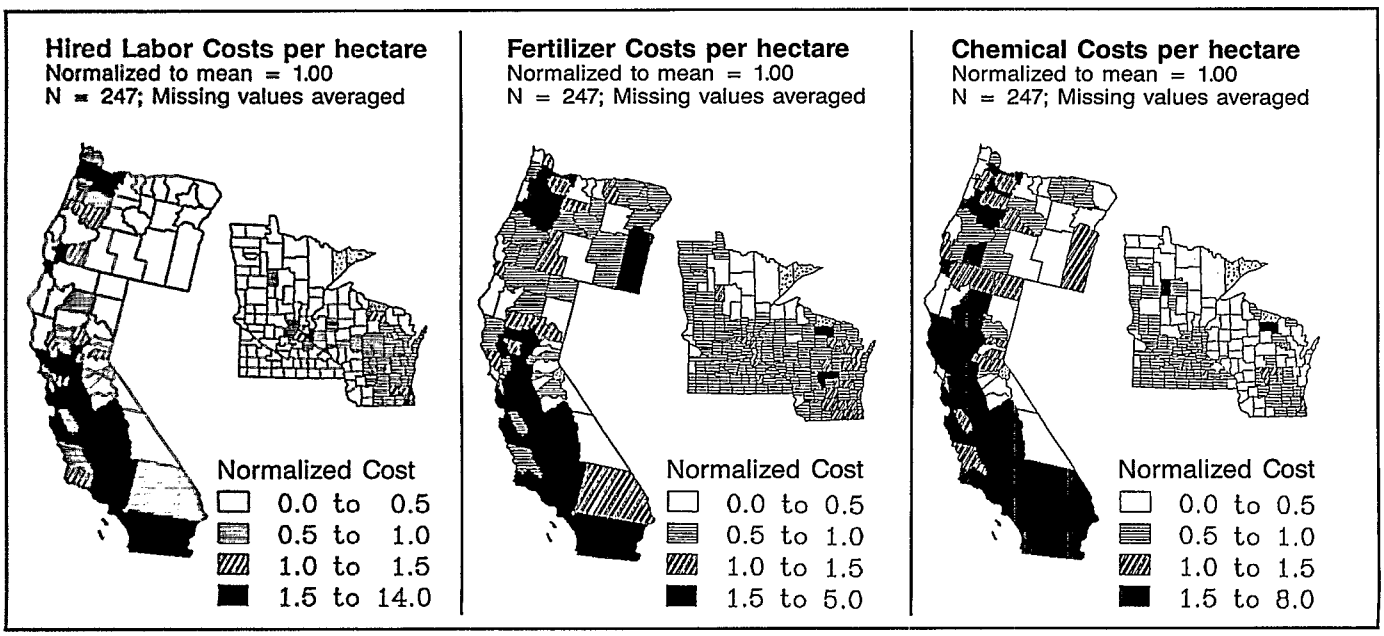

Figure 2. Hired labor costs, fertilizer costs, and chemical costs per hectare, normalized to mean = 1.00.

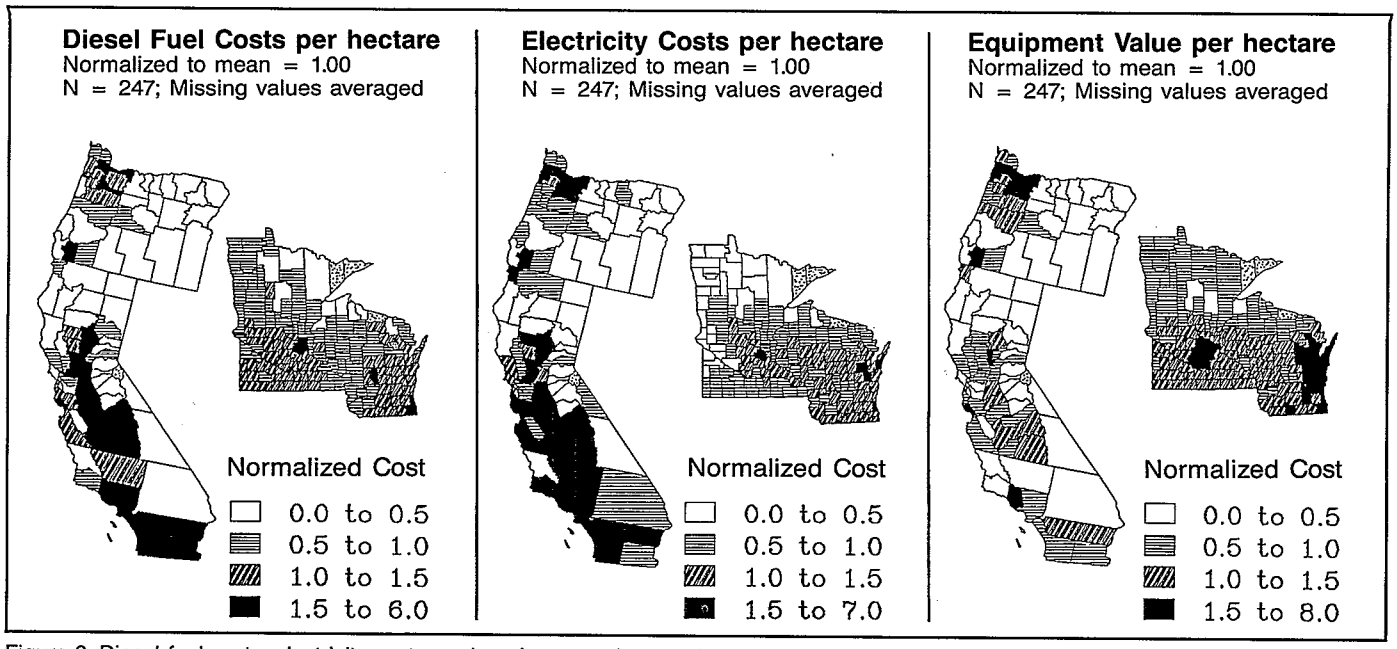

Figure 3. Diesel fuel costs, electricity costs, and equipment value, per hectare, normalized to mean = 1.00.

ment and where demand for nearby specialty crops might be high. But the similarity of urban areas to the Central Valley highlights the intensity of that particular region and points to the potential for targeting the area for sustainable management.

From the point of view of policy initiatives, these maps are helpful. They can aid in determining a program's effect on any individual input consideration. Unfortunately, low-input agriculture pertains to a complex system of many different management characteristics; looking at any individual input while excluding the influence of others is surely problematic. Therefore, we used statistical means to discern spatial patterns among the larger set of inputs, based on a Pearson product-moment correlation matrix.

A cluster analysis of the 14 basic farm inputs, using either the "raw" normalized variables or factor scores, provides a striking composite of the individual maps (Figure 4). Each of the spatial identities reappears with a clarity not seen in figures 2 and 3. The Central Valley appears solid, the Oregon split well-defined, and the Midwest tiering intact, with the exception of Onieda County, Wisconsin, which is not much of an agricultural area, so its county per-hectare averages are based on a small number of farms. The urban/rural dichotomy remains intact for the western states, but seems to collapse into the two most strongly urban midwestern counties—Ramsey, Minnesota, and Milwaukee, Wisconsin—perhaps because of the dominance of California's midsection in overall intensity.

In addition to the specific geographic identities, the input cluster result confirms four broader hypotheses concerning the usefulness of substate data analysis: lack of randomness, strong east-west bifurcation, ineffectiveness of state boundaries, and coherent multicounty regions. Each of these deserves brief elaboration.

When obvious geographical biases are removed, one might expect to find a random or illogical distribution of production costs across the study area. If southern California appeared to be quite similar to northern Minnesota, one would be hard-pressed to reveal the underlying causes. Likewise, if Wisconsin counties alternated intensity levels from one end of the state to the other, the implications would be rather uncertain.

The second theme extends from the first: these maps demonstrate significant differences in farm input intensity between the two pairs of states. Overall, the western states prevail in nearly every case, mostly, though not entirely, because of the Central

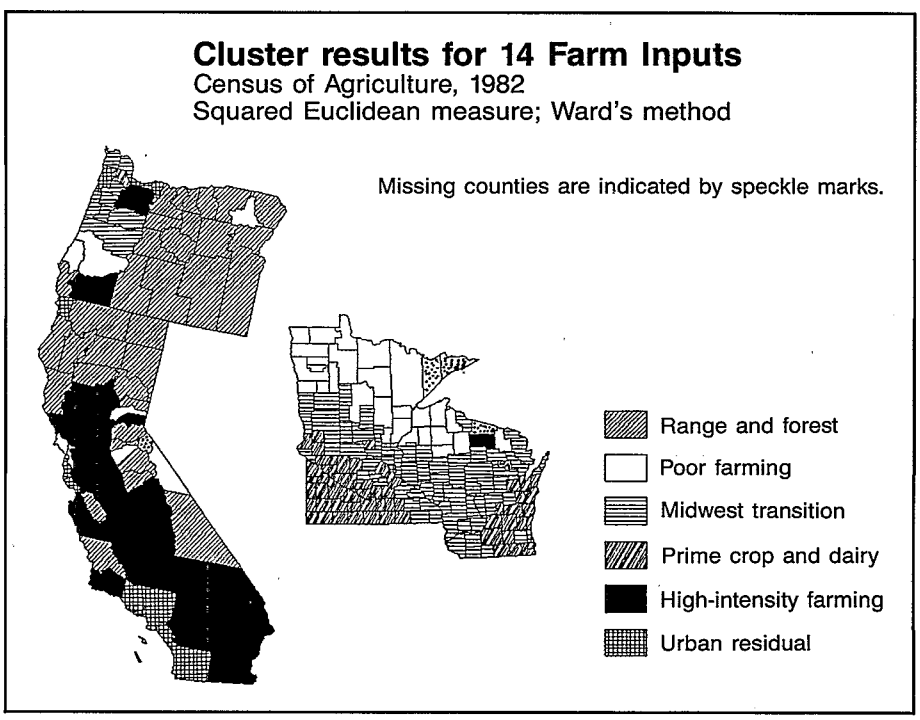

Figure 4. Cluster results for 14 farm inputs.

Valley region. In only one cluster group is there a considerable east-west overlap—the Midwest transition, also seen in northwestern Oregon. In fact, these two areas are quite similar in their climate, production diversity, and management practices as well. In general, a federal policy that targets all farmers as identical to one another would induce great inequities in these two pairs of states. It is likely that the free-ridership problem would only be magnified if the analysis were extended to the entire nation.

Thirdly, a state-by-state targeting system appears to be inappropriate, based on these results. As figure 4 suggests, the two state boundaries in our sample are completely inadequate for discerning one management practice from another. The regions used by the U.S. Bureau of the Census would divide Minnesota and Wisconsin into two management areas, west north central and east north central, respectively, which appear to be inappropriate for farm production issues. The Census regions were never intended to represent a scientific division of the states, yet many policy analysis studies use them as if they provided rational boundaries.

Finally, and most importantly, these normalized input values provide clear multicounty, coherent regions. While some outliers are always anticipated, there are strikingly few counties that isolate themselves from those around them. The regions are generally large enough to facilitate interjurisdictional planning, but not so unwieldy in their dimensions to undermine reasonable and prudent decision-making.

Conclusions and future research

Our analysis has shown that statistically and spatially significant regions exist for the purposes of targeting farm input management policies. The hypotheses of spatial randomness or nonsystematic arrangement of county-level farm intensity values were rejected outright. Furthermore, any suspicions that these data are bounded by state lines have been proven false. At least for the four-state area studied, the evidence for county-based, empirical regionalizations of agriculture is quite powerful. Perhaps most importantly, this research demonstrates the potential for empirically delineating areas of input intensity. Using data available in the public domain and a low cost, self-sufficient microcomputer, a decision-maker can readily learn of the current status of farming operations across a wide area and can compare input intensity with farm profitability levels to determine the effect of input reductions on sales.

Further, these input-based regions can be compared to other common foundations of regionalization. We have investigated the demographic characteristics of farm operators for the same four-state study area, and our preliminary findings strongly corroborate the results presented here. By integrating area-source emissions data from the U.S. Environmental Protection Agency, we are able to compare the role of various air pollutants with the intensity of agricultural production. We are also examining the responsiveness of regions based exclusively on input intensity with those delineated by commodity distinctions, for example, inputs for grain corn versus inputs for wheat. This question requires considerable study. Nonetheless, it is our contention that a commodity-based regional targeting system would be incapable of facilitating input reductions in highly diverse areas, such as California's Central Valley. With such a variety of commodities produced there, a policy that identifies each product separately would cause an administrative nightmare beyond the difficulties of interjuristictional politics.

Clearly, this research is in its infancy; there is much work still to be done. As we find these results encouraging, it is appropriate to expand the data base to the entire nation. There are a number of mathematical improvements to be considered: normalization changes, input-weighting alternatives, and missing-value manipulation challenges. Software improvements using the growing area of geographic information systems also offer considerable opportunities for further study and development.

As agricultural policy issues become increasingly complex, the need to identify specific targets for effecting postitive change will also expand. It is our hope that an integrated, data-based approach to policy development and analysis can be useful in the quest for environmental sustainability. □

Factors affecting farmers' use of practices to reduce commercial fertilizers and pesticides

Paul Lasley, Michael Duffy, Kevin Kettner, and Craig Chase

ABSTRACT: A survey conducted among a statewide random sample of Iowa farm operators explored the extent to which farmers rely upon a set of practices to reduce commercial fertilizer and pesticide use. The analysis examines the relationship between farmers' use of these practices with their opinions about low-input farming and their level of concerns about the health and safety of modern agricultural practices. These dimensions are explored by including selected sociodemographic characteristics of the operators in the analysis. Implications for the adoption and diffusion of low-input farming are discussed.

ONE of the most pervasive trends in U.S. agriculture has been the substitution of purchased inputs for farm-produced inputs (*1*). The substitution of commercial fertilizers and pesticides for animal manures and cultural practices to control insects and weeds has contributed to the increased reliance upon purchased inputs. Much of the increase in farm productivity since World War II is directly related to the use of commercial fertilizers and pesticides. As a result, in the last half of the 20th century there has been a steady growth in commercial fertilizer and pesticide use. In 1988, 96% of the corn and soybean acreage in the United States was treated with a herbicide and 97% of the corn received a chemical fertilizer treatment (*11*).

By the early 1980s, several unanticipated consequences of the heavy reliance upon chemical pest control and fertilizers began to emerge that questioned the long-term sustainability of modern agriculture. One of the first unanticipated consequences was the detection of agricultural chemicals in underground water supplies. Several studies have documented the incidence of pesticides and fertilizers in aquifers and wells (*7*). The detection of agricultural chemicals and fertilizers in groundwater raises serious concerns about long-term effects on the environment.

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A second issue closely related to the chemical contamination of the environment is the potential long-term health effects of chemical exposure for producers and consumers. The increased societal concerns about the health risks of the presence of agricultural chemicals in the food system has recently been the subject of several national media reports (*10*).

A third factor contributing to the re-examination of agricultural chemical use was the farm crisis of the 1980s and the need for producers to reduce production costs, particularly purchased inputs. In many cases, methods to reduce production costs has involved the substitution of farm-produced inputs for purchased inputs.

Alternative production systems

Because of the need to reduce production costs, growing concerns about environmental degradation, and the perceived health risks of agricultural chemical exposure, producers have become more receptive to alternative production systems (*5, 8*). For example, in the 1983 Iowa Farm and Rural Life Poll, 34% of the respondents ranked runoff of pesticides and fertilizers as the single most critical source of water pollution in the state. In the same survey, 75% supported diversifying Iowa agriculture by encouraging alternative crops to be planted and marketed (*3*). In the 1984 Iowa Farm and Rural Life Poll, 47% of Iowa producers supported allocating additional government research monies to assess the feasibility of organic farming methods (*4*). While low-input or sustainable agriculture is an ill-defined concept, its commonly accepted objectives are to conserve natural resources, minimize environmental impacts, enhance human health, contribute to national food goals, maintain long-term productivity, and enhance rural communities (*2*).

Methods and procedures

Our research posits that farmer adoption of low-input farming systems will be based upon their perceived need to maintain and protect the environment and whether they hold positive opinions about low-input farming methods. In addition, we assumed producer concern about the health and safety risks of conventional agricultural chemicals and fertilizers to be positively related to supportive opinions toward low-input farming systems.

Data for this analysis came from the Iowa Farm and Rural Life Poll, an annual survey of farm operators. Mail questionnaires were sent to a statewide, random sample of 3,270 farm operators in February 1989. Forty-eight questionnaires were returned by the post office as nondeliverable. This analysis is based upon 2,016 usable questionnaires, a response rate of 63%. When the characteristics of the respondents and their farm operations are compared with the 1987 Iowa census of agriculture, the survey provides a good cross section of Iowa farm operators.

Table 1. Iowa farmers' use of selected farm practices to reduce commercial fertilizer and pesticide use.

Practice	Do Not Use (1)	Limited Use (2)	Moderate Use (3)	Heavy Use (4)	Mean Score	Standard Deviation
	%					
Crop rotation	2	11	43	44	3.3	.73
Soil testing	6	20	47	27	3.0	.84
Mechanical cultivation	2	15	60	23	3.0	.68
Animal manure	21	24	34	21	2.6	1.00
Plant legumes	11	33	39	17	2.6	.90
Do your own scouting	10	29	46	15	2.7	.86
Integrated pest management	41	34	22	3	1.9	.86
Use degree days	48	31	19	2	1.8	.83
Employ prof. scouting service	85	10	4	1	1.2	.57
Nonconventional products	78	17	4	1	1.2	.56
Phermone traps for cutworms	91	5	3	1	1.1	.44

Reducing fertilizer and pesticides

The first objective was to examine the extent that farmers rely upon a set of accepted practices to reduce the use of commercial fertilizer and chemicals. Respondents were asked, "To what extent do you use the following practices to reduce commercial fertilizer and pesticide use?" The response categories for the 11 practices included were: 1 = do not use; 2 = limited use; 3 = moderate use; and 4 = heavy use.

Table 1 provides the distribution of responses to the set of practices that have been rank-ordered to facilitate reading the table. Forty-four percent of the respondents indicated that they make heavy use of crop rotations, and an additional 43% make moderate use of this practice. Twenty-seven percent reported heavy use of soil testing, and an additional 47% make moderate use of this practice. Nearly one-fourth (23%) of Iowa producers reported heavy use of mechanical cultivation, and another 60% make moderate use of this practice. Fifty-five percent reported making moderate or heavy use of animal manures. Legumes were used either moderately or heavily by 56% of the respondents. Scouting fields for insect, disease, or weed problems is another means to reduce chemical use. Sixty-one percent reported they relied upon their own scouting to a moderate or heavy degree. Only 5% reported employing a professional scouting service. One-fourth reported making moderate to heavy use of integrated pest management. About one-fifth (21%) indicated that they made moderate to heavy use of degree days. Nonconventional products and pheromone traps were used only moderately or heavily by less than 5% of the producers.

To assess whether the 11 practices could be combined into a summary scale, we performed a reliability analysis. The Cronbach alpha reliability coefficient for the 11 items was .64, which is within acceptable limits, indicating that the items would comprise a statisically reliable scale. A score of 11 indicates that the respondent does not use any of the practices, whereas a score of 44 would indicate heavy use of all 11 practices.

The mean score on the scale was 24.4, the median score was 24.0, and the standard deviation was 3.9 (Figure 1). From the distribution of scores it is evident that the farmers cannot be easily classified into groups, but rather it appears that a majority of them uses several of these practices to reduce commercial fertilizer and pesticide use.

Opinions on low-input farming

Respondents were asked to provide their opinions on seven attitudinal items designed to assess their level of agreement about the need for low-input farming methods. The question was stated, "There is increasing public concern about the safety of some modern agricultural practices. What is your opinion on these statements?" Respondents were asked to check a five-point scale that ranged from strongly agree to strongly disagree. Table 2 provides the responses to the seven attitudinal items. More than three-fourths (78%) of Iowa farmers agreed that modern farming relies too heavily on insecticides and herbicides, and 76% agreed that modern farming relies too heavily upon chemical fertilizer. Sixty-nine percent agreed that increased use of low-input farming practices would help maintain natural resources. Fifty-six percent agreed with the statement that farmers would use more low-input farming methods if more research information was available. Less agreement existed for the statement, "There is too much attention about the harmful effects of pesticides and too little about their benefits." Fifty-two percent agreed with the

statement, 35% disagreed, and 14% were uncertain. Farmers were divided about whether the need for an adequate food supply limits the use of low-input farming. Forty-five percent agreed with the statement, 27% were uncertain, and the remaining 27% disagreed. Thirty percent agreed with the statement, "There is too much concern about food safety issues." However, the majority of farmers, 54%, disagreed that there is too much concern about food safety issues.

These seven attitudinal items were subjected to a Cronbach's reliability test that produced an alpha coefficient of .74, indicating they could be combined into a summary scale. The scale ranged from 7, indicating low support, to 35, indicating strong support for low-input farming (Figure 2). The average score on the summary scale was 24.2 and the median was 24.0, with a standard deviation of 4.7. Farmers' opinions approximate a near normal distribution. While these data indicate that producers recognize farming's heavy dependence upon chemicals, support for low-input farming is widely dispersed across the farm population.

Health and safety concerns

Respondents were asked to indicate on a seven-point scale their level of concern about the health and safety risks of four agricultural practices (Table 3). The question posed to the respondents was this, "How concerned are you about the human health and food safety concerns of the following practices?"

Thirty-nine percent indicated they are very concerned about the aerial spraying of pesticides, (a score of 6 or 7). The mean score for this item was 4.9. Thirty-three percent reported being "very concerned" about the use of insecticides; the mean was 4.7. About one-fifth (21%) indicated high level of concern about the use of herbicides. Only 10% of the respondents rated the use of chemical fertilizer as a high level of concern.

A Cronbach's reliability analysis was performed that indicated the items could be combined into a summary score. The alpha coefficient of reliability was .79. The average score on the summary scale was 17.2; the median value was 17.0 (Figure 3). The range on the summary scale was from 4, indicating "no concern," to 28, if the respondent was "very concerned" about each of the practices. The resulting distribution, while approximating a normal distribution, shows a couple of interesting features. The spikes on values 16 and 28 suggest that farmers are moderately concerned and that approximately 6% indicated high concerns on each of the four practices.

Who is concerned?

There is a wealth of social science research on the importance of sociodemographic variables in explaining farmer's opinions and adoption of new technology (*9*). Three prominent variables in adoption research are the operator's age, education level, and farm size. To assess whether these variables were related to respondent's use of practices to reduce agricultural chemicals and fertilizer and their opinions about low-input farming systems and to perceived health and safety concerns, a one-way analysis of variance and zero-order correlation were computed (Table 4).

Younger farm operators, defined as those under 40 years of age, were more likely to use the set of practices to reduce chemical inputs than were older farmers (60 years or older). The average score for farmers under 40 years of age was 25.3 compared to 23.5 for those operators over the age of 60. Using uncategorized data, zero-order correlation coefficients were computed to assess the direction and strength of the relationships. The zero-order correlation between operator's age (using raw scores) and use of the practices was r=−.17, indicating a modest negative relationship between operator's age and using these practices to reduce fertilizer and pesticide use.

Operators' education was positively related to use of the practices to reduce chemical inputs, although the relationship was weak, (r=.06). Operators with less than a high school education (less than 12 years) were less likely to use the practices than were operators with 4 or more years of post-secondary education.

Farm size as measured by total cropland acres was positively related to use of the practices, although the relationship was

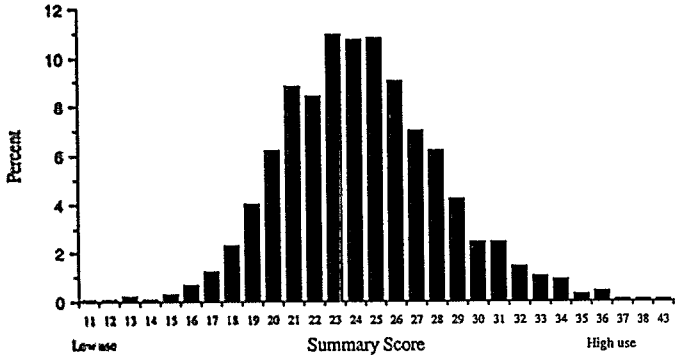

Figure 1. (left) Summary score of Iowa farmers' use of selected practices to reduce commercial fertilizer and pesticide use.

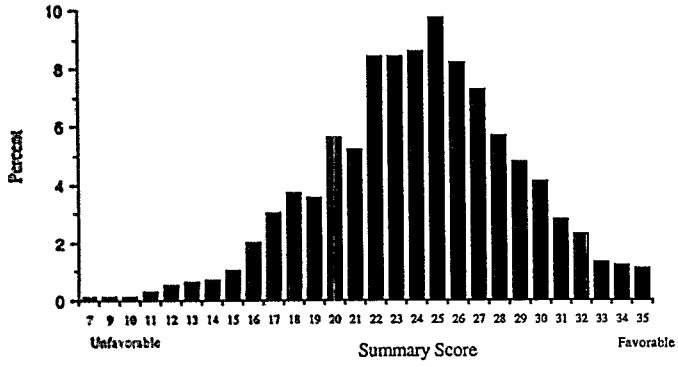

Figure 2. (below, left) Summary score of Iowa farmers' opinion about low-input farming.

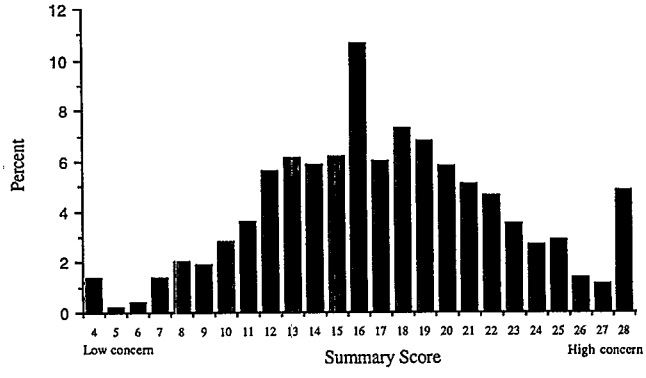

Figure 3. (below, right) Summary score of Iowa farmers' concern about the health and safety risk of selected agricultural practices.

Table 2. Iowa farmers' opinions on agricultural practices.

Practice	Strongly Agree (5)	Somewhat Agree (4)	Uncertain (3)	Somewhat Disagree (2)	Strongly Disagree (1)	Mean Score	Standard Deviation
	%						
Modern farming relies too heavily upon insecticides and herbicides	40	38	5	13	3	4.0	1.1
Modern farming relies too heavily upon chemical fertilizer	34	42	6	15	4	3.9	1.1
Increased use of low-input farming practices would help maintain our natural resources	21	48	19	11	2	3.7	9.7
Farmers would use more low-input farming methods if more research information was available	14	42	30	11	2	3.6	.93
There is too much attention about the harmful effects of pesticides and too little about their benefits*	14	38	14	23	12	2.8	1.3
The need for an adequate supply of food limits the use of low-input farming practices on a commercial basis*	8	37	27	21	6	2.8	1.1
There is too much concern about food safety issues*	6	24	14	36	19	3.4	1.2

*Reversed coded in computing scale.

weak (r=.08). Operators of farms greater than 460 acres were somewhat more likely to use the set of practices to reduce chemical and fertilizer use than operators of farms less than 140 acres. Operators of farms less than 140 acres had a mean of 23.6 on the reduction scale compared to 24.9 for operators of 460 or more crop acres.

Operator age and education level were not related to opinions about low-input farming methods. However, there was a moderately strong negative relationship between cropland acres and support for low-input farming. The zero-order correlation for this relationship was −.25. Operators of farms of less than 140 acres had a mean score of 25.7 compared to 22.6 for operators of farms greater than 460 acres.

Farm operator age was positively related to perceived health and safety concerns of the four agricultural practices, although the relationship was weak (r=.06). There was a modest negative relationship between operator education levels and health concerns (r=−.08). Operators with 13 or more years of formal education were less likely to express concerns about health and safety of agricultural practices than operators with less than 12 years of education. Farmers with less than 12 years of education had a mean score of 18.1 on the health concern scale compared to 16.5 for operators with 13 or more years of education.

Farm size as measured by total cropland acres was negatively related to operators' concerns about health and safety issues. Larger farm operators were less concerned about health and safety issues of the four practices than were operators of smaller farms. The mean score for operators of farms less than 140 acres was 18.6 compared to 15.9 for operators of farms greater than 460 acres. The measure of association between total cropland acres and health concerns was −.19.

Figure 4 presents the correlations across the three composite scales. Supportive opinions about low-input farming do not appear to be associated with use of the practices to reduce chemical inputs (r=.05). The absence of a strong positive relationship between these scales suggests that producers are using these practices independent of their opinions about low-input farming.

Concerns about health and safety of agricultural practices were positively related to use of the practices to reduce chemical use (r=.10). This finding suggests that use of low-input, sustainable practices are modestly related to perceived health and safety

Table 3. Iowa farmers' concern about the health and safety of agricultural practices.

Practice	No Concern 1	2	Moderate Concern 3	4	5	Very Concerned 6	7	Mean Score	Standard Deviation
	%								
Aerial spraying of pesticides	3	5	11	26	16	17	22	4.9	1.6
Use of insecticides	3	6	14	25	19	17	16	4.7	1.6
Use of herbicides	4	11	20	28	16	11	10	4.2	1.6
Use of chemical fertilizer	10	19	23	27	11	4	6	3.5	1.6

Table 4. Mean scores of farmers' use of reduction practices, assessments of low-input farming, and health concerns by selected socioeconomic variables.

Socioeconomic Variable	Reduction Practices	Support for Low-Input Farming	Health Concerns
	Mean Scores		
Operators' age			
Under 40	25.3	23.8	16.2
41-50	24.6	24.2	17.9
51-60	24.4	24.3	17.2
Over 60	23.5	24.4	17.3
	F-ratio* 15.45†	F-ratio 1.66 NS‡	F-ratio 6.90†
	r§ = −.17†	r = .05 NS	r = .06†
Operators' education			
Less than 12 years	23.8	24.6	18.1
12	24.3	24.3	17.4
13-15	24.7	23.9	16.5
16 or more	24.8	24.0	16.5
	F-ratio 3.2#	F-ratio 1.33 NS	F-ratio 7.39†
	r = .06#	r = −.03 NS	r = −.08†
Total cropland (acres)			
Under 140	23.6	25.7	18.6
141-270	24.3	24.3	17.1
271-460	24.9	23.9	16.9
460 or more	24.9	22.6	15.9
	F-ratio 10.95†	F-ratio 37.05†	F-ratio 27.6†
	r = .08#	r = −.25†	r = −.19†

* The appropriate statistical test to assess the difference in mean scores is the F-ratio that permits one to determine if the differences among the means are statistically significant (6).
† Statistically significant at p ≤.01.
‡ NS = Nonsignificant.
§ In addition, using uncategorized interval data a Pearson zero-order correlation was computed as a measure of association between the variables. This measure can vary from −1.0 indicating a perfect negative relationship to +1.0 indicating a perfect positive relationship. Thus, the measure provides the relative strength as well as the direction of the relationship.
# Statistically significant at p ≤.05.

risks of agricultural practices.

A strong positive association exists between perceived health and safety concerns and support of low-input farming (r=.57). Concern about health and safety issues of agricultural practices were strongly related to favorable opinions about the need for low-input farming methods.

Summary and conclusions

We argue that support for low-input farming is based upon farm operators' concern about environmental degradation and perceptions about the health and safety of agricultural practices. Our examination of the extent to which Iowa farmers use a set of practices to reduce commercial fertilizer and pesticide use showed that it is difficult to categorize farmers on the basis of the set of practices they use. Contrary to some who view producers as representing either the low-input or conventional farmers, the data suggests that use of practices to reduce agricultural chemical use are normally distributed across the farm population. Thus, it may be more fruitful to view the use of these reduction pretices as representing a continuum rather than discrete types of users. In addition, while support for low-input farming methods was positively related to use of the practices to reduce chemical and fertilizer use, the relationship was weak.

The data show that producers are concerned about the health and safety risks of modern agricultural practices, and these concerns are strongly related to supportive opinions about low-input farming.

A third conclusion from these data is the relative unimportance of operator age and education in explaining either use of practices to reduce chemical use, opinions about low-input farming, or concerns about health risks.

Farm size as measured by total crop acres is important in explaining farmers' use of reduction practices, opinions about low-input farming systems, and perceptions of health risks posed by some modern agricultural practices. Larger farm operators are somewhat more likely to use the set of practices to reduce chemical use but were less likely to hold supportive opinions about low-input farming and were less concerned about the adverse health risks posed by modern farming practices than operators of smaller farms. Perhaps this is because larger farmers have already implemented many of the practices that lead them to be less supportive of low-input farming. Nevertheless, among all Iowa farmers there appears to be considerable support for pursuing low-input farming methods, and much of this support appears to be related to producer concerns about health and safety.

The findings provide strong evidence that Iowa farmers recognize the heavy dependence of farming upon commercial fertilizer and pesticides. Further, there appears to be strong support among farmers to pursue research and generate information to assist farmers in using low-input farming systems.

Finally, it appears that more efforts need to be devoted to gaining farmers' acceptance and use of existing recommended practices to reduce fertilizer and chemical use. For example, 26% of the respondents reported that they either do not use or make limited use of soil testing. Eleven percent do not plant legumes, and another one-third make limited use of legumes in their farming operations. Future research should focus on factors or barriers preventing farmers from using the accepted and generally recommended practices that can reduce chemical and fertilizer use. More research on the factors preventing farmers from using these accepted practices may well be the first step toward the transition to a low-input, sustainable agriculture.

The future success of low-input, sustainable farming systems depends upon farmers' capacities to manage complex agronomic systems. A common thread across the literature on low-input farming systems is the higher level of management skills that are required to minimize inputs. The capacity of farmers to manage such systems may be the limiting factor in making progress toward a low-input farming system. The transition to low-input farming systems will require that technical and human factors be closely integrated.

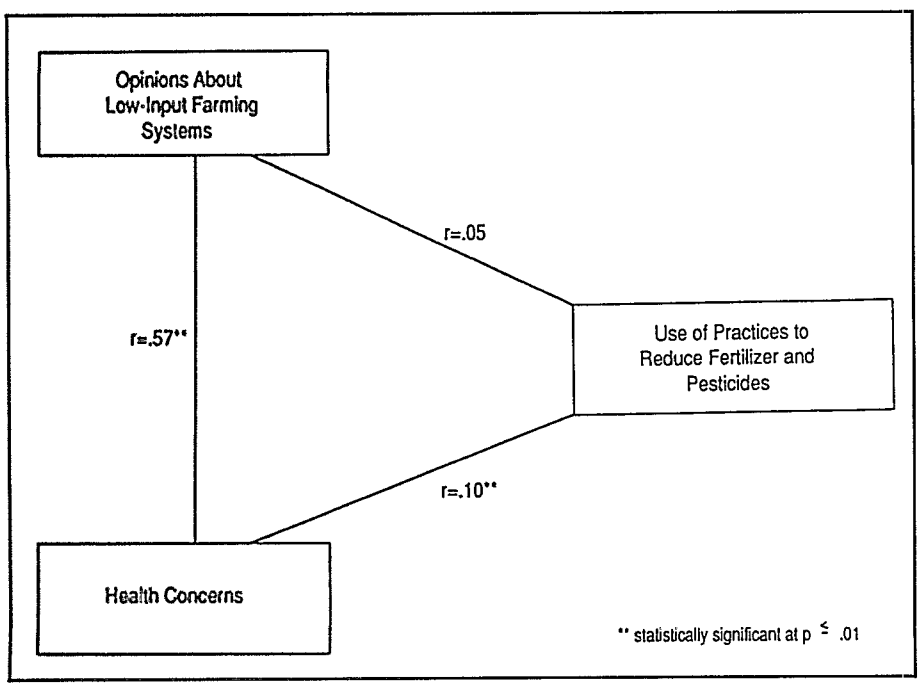

Figure 4. Correlations across the three composite scales.

REFERENCES CITED

1. Cochrane, Willard W. 1979. *The development of American agriculture, A historical analysis.* Univ. Minn. Press, Minneapolis.
2. Duffy, Michael. 1989. *Economic consideration in low-input sustainable agriculture.* Dept. Econ., Iowa State Univ., Ames.
3. Lasley, Paul. 1983. *The Iowa farm and rural life poll summary.* Pm-1130. Coop. Ext. Serv. Iowa State Univ., Ames.
4. Lasley, Paul. 1984. *The Iowa farm and rural life poll summary.* Pm-1178. Coop. Ext. Serv. Iowa State Univ., Ames.
5. Lasley, Paul, and Gordon Bultena. 1986. *Farmers' opinions about third-wave technologies.* Am. J. Alternative Agr. 1 (summer): 122-126.
6. Loether, Herman J., and Donald G. McTavish. 1974. *Inferential statistics for sociologists, An introduction.* Allyn and Bacon, Inc., Boston, Mass.
7. Nielsen, Elizabeth G., and Linda K. Lee. 1987. *The magnitude and costs of groundwater contamination from agricultural chemicals: A national perspective.* Agr. Econ. Rpt. 576. Econ. Res. Serv., U.S. Dept. Agr., Washington, D.C.
8. Padgitt, Steve. 1990. *Farmers' view on groundwater quality: Concerns, practices and policy preferences.* Office Tech. Assessment, Washington, D.C.
9. Rogers, Everett M. 1983. *Diffusion of innovations.* The Free Press, New York, N.Y.
10. Time magazine. 1989. *Is anything safe?* March 27:13.
11. U.S. Department of Agriculture. 1989. *Agricultural resources, situation and outlook.* AR13. Econ. Res. Serv., Washington, D.C. □

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Sustainable production from the Rough Fescue Prairie

Johan F. Dormaar and Walter D. Willms

ABSTRACT: Native prairie communities have evolved to produce relatively low but sustained production. Demand for greater production has resulted in overgrazing and, consequently, lower and more unstable annual yields and increased risk of soil erosion. Because the Rough Fescue Prairie is best suited for grazing, studies were made to determine its carrying capacity and assess the effects of overgrazing. Overgrazing resulted in an increase in plant species that were shallow-rooted and less productive, but more resistant to grazing. This was associated with higher soil temperatures and reduced infiltration. Consequently, the soil was transformed to one characteristic of a drier microclimate. Soil color changed from black to dark brown as stocking rate increased from light to very heavy. Grazing caused a redistribution of nitrogen in the soil by concentrating a greater proportion in a shallower Ah horizon. Productivity deteriorated rapidly with overgrazing, but more than 20 years of drastically reduced stocking rates are required to enable recovery.

RANGELANDS are unsuited to cultivation because of such physical limitations as low and erratic precipitation, rough topography, poor drainage, and cold temperatures (*18*). Instead, rangelands are a source of forage for free-ranging native and domestic animals. In many areas, rangelands are also a source of wood products, water, and recreation. Native prairie represents a major forage-producing component of rangelands.

In Canada, there are 13.6 million ha (33.6 million acres) of native prairie. Of these, 6.5 million ha (16.1 million acres) are in Alberta. About 13% of Alberta's native prairie is classified as the Rough Fescue Prairie association, with the majority being in the Foothills.

The Rough Fescue Prairie historically has been the home of many animal species, the most conspicuous of which was the plains bison (*Bison bison bison* Linnaeus). It is believed that bison used this prairie for their wintering grounds (*16*) by taking advantage of the relatively good quality grass and the presence of warm chinook winds that ensured access to it by eliminating snow cover. Although information is scarce, it appears that mankind's first attempt to manage the prairie resource involved burning the range to eliminate excess litter as a means of attracting bison into an area for hunting. This was likely done in the fall or spring, while plants were dormant and the herbage flammable.

The native people lived off the land and existed by not exceeding the land's production capabilities. Although production was low, their subsistence was assured until the arrival of European settlers in the 1800s. With the introduction of livestock and the plow, production took on a new meaning; management could best be defined as exploitation when settlers removed buffers that had previously allowed stable production. The result was a fluctuating boom-and-bust cycle that depended on current moisture conditions.

The prolonged drought in the 1920s and 1930s and the inability to farm on a viable scale due to the short growing season and the unevenness of the terrain caused many settlers to abandon the land. These circumstances ensured that the primary agricultural value of the Rough Fescue Prairie would be for livestock grazing. However, without proper knowledge of its carrying capacities, much of the grassland was overgrazed and deteriorated. Science has allowed the return to sustained production, but at a higher level of efficiency than was achieved by either the native people or European settlers.

The Rough Fescue Prairie in western Canada is found on highly productive soils, but cultural practices are limited by steep terrain. Consequently, management of grassland vegetation is through management of grazing by cattle (*23*). This is normally accomplished using a continuous grazing system where the cattle are turned onto the range in spring and removed in autumn. The most critical management decision is to determine a stocking rate so that livestock production per unit area of rangeland is maximized while the forage resource is maintained over time.

Jenny (*9*) suggested that soil is a function of an initial state represented by parent material and topography, by the age of the system, and by influx variables represented by climate and the biotic factor. Because soils are, therefore, dynamic natural bodies, the physical presence of domestic animals, together with the concomitant changes in the range vegetation, will act upon and affect the soil resource. Herein, we describe the historical nature of productivity on the Rough Fescue Prairie and examine some buffering processes that allow stable and sustainable biomass production.

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Study methods

The study, located at the Agriculture Canada substation in the Porcupine Hills near Stavely, Alberta, began in 1949 to determine the carrying capacity of the Rough Fescue Prairie. Four fields, with a permanent exclosure [0.5 ha (1.2 acres)] in each to provide a control, were fenced to enclose areas of 65, 49, 32, and 16 ha (160, 120, 80, and 40 acres) (*23*). Each field was stocked with 13 cow-calf pairs from mid-May to mid-November in each year of the study to the present (1989). This resulted in fields stocked at four different rates: light, 1.2 animal unit months (AUM)/ha (0.49 AUM/acre); moderate, 1.6 AUM/ha (0.65 AUM/acre); heavy, 2.4 AUM/ha (0.98 AUM/acre); and very heavy, 4.8 AUM/ha (1.95 AUM/acre).

The very heavily stocked field supported 4.8 AUM/ha until 1959. While stocking with 13 cow-calf pairs continued in the following years, declining forage productivity necessitated removing the cattle at various times since then. Grazing in that field was terminated when the cows began losing weight, which occurred when use of available forage was about 80%. Consequently, after 1960 the stocking rate on the very heavily stocked field varied from 2.5 to 4.8 AUM/ha and averaged 3.2 AUM/ha; the planned stocking rate was achieved only twice, in 1972 and again in 1989.

The topography of the site is undulating, varying in elevation from 1,280 to 1,420 m (4,200 to 4,658 feet) above sea level. The climate is dry subhumid with a mean annual precipitation of 550 mm (21.6 inches). The pedon has been classified as Orthic Black Chernozemic or Argic Cryoboroll fine, montmorillonite developed on till overlying sandstone (*2*). Table 1 describes this soil. The vegetation is typical of the Rough Fescue Prairie association (*13*), with rough fescue (*Festuca campestris* Rydb.) representing about 44% basal area of vegetation and Parry oat grass (*Danthonia parryi* Scribn.) about 23%; the balance is comprised of an assortment of grasses, forbs, and shrubs (Table 2).

Results and discussions

Effects of grazing. The greater stocking rate resulted in increased forage use (Table 2), which resulted in increased grazing pressure. This corresponded to a reduction in range condition and an increase in grazing-resistant species that were shorter, less-

productive, and shallow-rooted. Rough fescue was replaced by Parry oat grass, bluebunch fescue *Festuca idahoensis* Elmer), wheat grass (*Agropyron* spp.), and June grass (*Koeleria cristata* (L.) Pers.). Prolonged heavy grazing pressure resulted in a cover of weedy species, including pasture sage (*Artemisia frigida* Willd.), locoweed [*Oxtropis campestris* (L.) DC.], pussy-toes (*Antennaria* spp.), and dandelion (*Taraxacum officinale* Weber) (*23*). Bare ground increased from zero to 15% on the very heavily grazed range (*14*). The effect on annual production was a shift from stability at a reasonably high level of about 2,000 kg/ha (1,780 pounds/acre) to one that was closely linked with current precipitation and, therefore, highly variable and, on average, only about 50% of maximum (Table 2).

Vegetation changes led to a reduction of organic matter and a loss of soil structure, which contributed to surface sealing, reduced infiltration rates (Table 3), and, presumably, increased evaporation. The net effect was reduced soil water (*10, 11, 17*). Not only did evaporation increase but there was also less snow catch. Over time, this caused the character of the soil to change to that of a drier microclimate associated with warmer temperatures in the summer (Table 3) and a change in soil color in the Ah horizon. Soil color (dry) changed from black (10YR 2/1) under light grazing, to very dark gray (10YR 3/1) under moderate grazing, to dark grayish brown (10YR 3/2) under heavy grazing, and to dark brown (10YR 3/3) under very heavy grazing (*12*). The change in soil color was correlated with a change in soil organic matter from 11.7% under light grazing to 9.7% under very heavy grazing over 20 years (Table 3). Evidence of this transformation also was observed on a nearby range that was managed with a short-duration grazing system (*5*). Over a 5-year period, grazing that removed about 80% of available forage resulted in a change in color from 5YR 2/1 to 5YR 2/2-3/2 (dry), suggesting either a loss of organic matter or differential rates of accumulation.

Areas that are predominantly in grassland generally are designated as having limited potential for severe erosion (*1*). This leaves the perception that native prairie cannot erode, no matter how badly overgrazed it is. However, livestock activity can affect the water-intake characteristics of the soil (*11*) by removing cover and by compacting the soil. Provided the soil was covered by vegetation, type of cover had little influence on water-intake rate. However, as grazing intensity increased, water intake decreased. Water-holding capacity, representing field water capacity plus the water held in organic matter, of undisturbed cores was lower in heavy grazing treatments than in light grazing treatments (*14*). The consequence of reduced infiltration and water-holding capacity was increased runoff. Soil erosion by water began when about 15% of the soil surface became bare (*11, 14*). This condition was present only in the very heavily stocked field and appeared to reduce the depth of the Ah horizon by 4 cm (1.6 inches) (*4*).

Water infiltration is influenced by bulk density, which is affected by large animals that exert physical pressure on the soil by their weight (*8*). The effect of animals on bulk densities is also a function of stocking rate, which describes the frequency and duration of impact. On the Rough Fescue Prairie, bulk densities in the surface 0 to 10 cm (0 to 4 inches) increased from about 0.75 Mg/m³ in the exclosures within each field to 0.83 Mg/m³ in the lightly grazed field and 0.90 Mg/m³ under heavy grazing (Table 4) (*14*). However, frost action over winter had an ameliorating effect (*5, 19*).

Increasing the grazing pressure caused an increase in the excreta load which, together with increased bulk densities and decreased water-intake characteristics, has serious ramifications for water quality. Total nitrogen (N) content (in percent) increased with very high grazing pressure even though total N in the Ah horizon remained the same (Table 3). Total N was less mineralizable and potentially not as available but more acid-hydrolyzable at the very high stocking rates. This means that a redistribution of the N within the system occurred (*4*). The increased excreta loads affect soil and water quality in processes that are complex and still not well understood.

Denitrification losses have been more pronounced in undergrazed than in overgrazed grassland soils (*7*), possibly due to cooler temperatures (*5, 12*) and more water present (*11, 12*) in the former soils. Plant species that increase or invade as a consequence of overgrazing tend to produce root extracts that inhibit nitrification (*15*). Nitrification may be a mechanism whereby these plants conserve the low amounts of N available in grassland soils.

Persistent trampling affects the physical and chemical characteristics of soil over an entire field (*5*) but also on microsites within a field (*21*). To maintain plant vigor and to allow carryover in the following year, range is stocked season-long at a moderate rate. This leads, however, to the formation of patches where intensive trampling on microsites also increases bulk densities (*21*). Higher bulk densities were found on paths (0.92 Mg/m³) than in grazed (0.89 Mg/m³, $P>0.05$) areas (*14*). Further, soil organic matter, carbohydrates, and depth of the Ah horizon were greater ($P>0.05$) in undergrazed patches, while urease activity, nitrate N, ammonium N, and available phosphorus were greater ($P>0.05$) on overgrazed patches (Table 4). This confirmed earlier field-based conclusions.

Although the effects of livestock on rangeland are dramatic and highly visible, native animals also have contributed to the erosion

Table 1. Pedon description of the Orthic Black Chernozemic soil at the Agriculture Canada Substation, Stavely, Alberta (*4*).

Horizon	Thickness (cm)	Description
Ah_1	14 to 20	Black (10YR 2/1, moist) clay loam; moderate fine granular; soft, very friable; mildly acidic.
Bm_1	8 to 21	Dark yellowish brown (10YR 3/4, moist) clay loam; weak, fine subangular blocky; neutral.
Bm_2	12 to 20	Dark yellowish brown (10YR 4/4, moist) loam to clay loam; moderate coarse, prismatic to subangular blocky; firm; neutral.
Ck	8	Yellowish brown (10YR 5/4, moist) with very pale brown (10YR 8/3, moist) clay loam; angular blocky; friable; strongly effervescent; mildly alkaline.

Table 2. Long-term effects of grazing at fixed stocking rates on species composition (percent of basal area) in the Rough Fescue Prairie and on forage production and use (*22, 23*).

	Stocking rate (AUM/ha)				
	0	*1.2*	*1.6*	*2.4*	*4.8**
	% of basal area				
Species composition					
Graminoids	80.1	72.3	66.8	76.6	62.7
Parry oat grass	23.4	24.5	32.7	48.0	35.3
Idaho fescue	5.0	5.2	5.6	12.5	11.9
Rough fescue	43.8	37.7	20.7	7.9	2.5
Other graminoids	5.1	2.2	4.0	2.1	3.3
Forbs	11.6	18.5	20.4	18.0	31.8
Shrubs	8.3	9.2	12.8	5.4	5.5
Available forage (kg/ha)	—	2199	2171	1865	1170

*This rate was achieved until 1959, but was variable thereafter.

potential. Prior to the settlement of the prairies, terrifying flashfloods often led to abrupt rises of streams and quick inundation of lowlands. This was blamed, at the time, on the vast herds of bison that trampled the ground until it was impervious to water (*3*). Presently, the greatest impact may be from pocket gophers (*Thomomys talpoides talpoides* Richardson) that have markedly influenced the development of rangeland soils during the thousands of years they have inhabited North America (*20*). However, unlike the bison, which have long since disappeared from the prairies, even the pocket gopher is influenced by livestock activity. Together, they compound the erosion problem.

Soil movement as a result of gopher activity within the study area was examined by Shantz (*17*). On areas that were suitable for pocket gophers in each of the four fields, soil displacement increased with the degree of grazing. Soil displacement was three times as great in the very heavily grazed field as in the heavily grazed field and seven times as great as in the lightly grazed field. That is, soil displacement on areas of poor range, as defined by Johnston and associates (*12*), was double that of good range and six times that of excellent range.

Soil temperatures also correlated with the activity of pocket gophers. More than four times more soil was displaced on sites having high soil temperatures (16 °C in June) than on sites having moderate temperatures (13 °C) or less (*17*). Although gophers may not be attracted to warmer soil temperatures per se, their presence indicates sites that are drier and that have less dead vegetation and more palatable regrowth. Soil disturbance by the pocket gopher exacerbated soil creep on slopes caused by tramping by livestock (*19*).

Grazing effects are imposed either on a short or long term, and their duration, after corrective action is taken, may be described similarly. Retrogression in the composition of plant species, caused by overgrazing occurs rapidly, but succession, following rest from grazing, is slow (*23*). The rate of retrogression and succession depends upon the plant species and grazing pressure. Rough fescue began to decline immediately after imposing very heavy grazing pressure and was nearly eliminated after 5 years, while range condition reached a minimum after 13 years (*23*). Succession of the plant community to a near climax state required more than 20 years of rest (*23*).

While vegetation responds rapidly to grazing, the soil response is delayed because at least some effect is through the plant. However, soil effects were noted 18 years after very heavy grazing pressure was imposed

Table 3. Effects of long-term, fixed stocking rates on the physical and chemical properties of soil on the Rough Fescue Prairie (*4, 12, 14, 17*).

Soil Property	*Stocking rates (AUM/ha)*				
	0	*1.2*	*2.6*	*2.4*	*4.8**
Bulk density (Mg/m³ 0 to 10 cm depth)	0.75[a†]	0.83[b]	0.80[b]	0.83[b]	0.90[c]
Infiltration rate (cm/hr, 0 to 1 min.)	132[c]	103[bc]	96[b]	76[ab]	56[a]
Soil loss (kg/ha)†	—	54	16	16	1,219
Temperature (°C, 15 cm depth in June)	—	11[a]	12[a]	13[a]	16[b]
Water (% of dry soil in June)	—	53[c]	49[bc]	42[b]	32[a]
Organic matter (%)	—	11.7[a]	11.2[a]	10.7[a]	9.7[a]
Total N (% in Ah horizon	0.93[a]	0.94[a]	—	—	1.10[b]
Total N (t/ha in Ah horizon)	12.96	12.94	—	—	13.07
Mineralizable N (μg/g of soil)	73.9[c]	66.2[b]	—	—	49.8[a]
Hydrolyzable N (% of total N)	74.9[a]	82.5[b]	—	—	85.0[b]

*This rate was achieved until 1959, but was variable thereafter.
†Means within a row followed by the same letter do not differ significantly ($P > 0.05$); means without letters were not analyzed statistically.
‡Based on simulated rainfall at a rate of about 8.5 cm/hr.

(*12*). A stable minimum level of soil quality or an estimate of recovery has not been made, although new evidence obtained from a study of abandoned cropland indicates that more than 75 years are required for recovery of some chemical constituents (*6*).

The cost of overgrazing must be evaluated over the long term, for which evidence is only speculative. Strictly in terms of beef production per unit area, greatest yields were obtained with maximum use, although individual animal gains and forage productivity declined (*22*). However, overgrazing reduced management stability as forage production became more closely linked with current precipitation. Consequently, forage production became unpredictable and reliance on preserved forages increased. With continued heavy grazing pressure, reduced productivity and increased instability are likely to increase over the long term as soils continue to degrade.

Table 4. Soil characteristics on overgrazed and undergrazed patches on Rough Fescue Prairie (*21*).

Soil Characteristic	*Overgrazed*	*Undergrazed*
Organic matter (%)	11.48	13.13[b]
Carbohydrate (mg/g)	5.30[a*]	6.69[b]
Urease activity (g N/kg)	0.16[b]	0.14[a]
Nitrate N (mg/kg)	10.01[b]	5.14[a]
Ammonium N (mg/kg)	8.46[b]	5.14[a]
Available P (mg/kg)	6.04[b]	3.85[a]
Ah (depth, cm)	16.10[a]	22.40[b]

*Paired means with the same letter do not differ significantly ($P > 0.05$).

The cost of overgrazing may be evaluated as the reduction in forage and, subsequently, animal production. But this does not take into account the cost of destroying the watershed or wildlife habitat. One approach in assessing the cost to agriculture only is to determine the reduction in stocking rate necessary to bring the range back to a condition that will support the various resources. With the assumption that optimum resource exploitation will occur near the climax state of the community, stocking rates can be set to achieve that goal (*24*). Consequently, the stocking rate on degraded range will be reduced, depending on the degree of degradation, and the cost of recovery, determined as the cost of providing alternate forage. For the Rough Fescue Prairie, a 50% reduction in stocking rate will be required to allow recovery from a degraded condition to an acceptable one (*24*). Although stocking may be increased gradually over time, more than 20 years will be required before the optimum rate is reached.

Conclusions

The physical presence of domestic animals, with the additional excreta load and effects on range vegetation, acts upon and affects the soil resource in a manner that is often detrimental. Because of increased bare ground and bulk densities and reduced water intake, anthropogenic erosion, which is exacerbated by pocket gopher activity, increases while the Black Chernozemic soil acquires characteristics associated with soils of a drier microclimate. Consequently, the quality of soil deteriorates, as does the

quality of water in terms of storage and loading of sediments and nutrients. A stocking rate of 1.6 AUM/ha is certainly worth considering for the Rough Fescue Prairie because that rate maintains soil quality, productivity, and economic returns.

Despite a switch from native to domestic animals, properly managed range can sustain agricultural productivity and conserve related resources. Plants should not be grazed too early in spring when they are mobilizing resources for growth. Grazing should remove only about 50% of current production to avoid removing stored energy in the stem bases and to allow for carryover into the next year. The carryover not only provides emergency forage but, more importantly, sustains the nutrient status and hydrological properties at an optimum level, thereby stabilizing annual production.

REFERENCES CITED

1. Agriculture Canada - Alberta Agriculture. 1986. *Potential for wind erosion map in southern Alberta 1986.* Edmonton, Alta.
2. Cannon, M. E. 1983. *Estimating range production from thickness of mollic epipedon and other soil or site characteristics.* M.Sc. thesis. Mont. State Univ., Bozeman.
3. Connell, E. S. 1984. *Son of the morning star.* North Point Press, San Francisco, Calif.
4. Dormaar, J. F., S. Smoliak, and W. D. Willms. 1989. *Vegetation and soil responses to short-duration grazing on Fescue grasslands.* J. Range Manage. 42: 252-256.
5. Dormaar, J. F., S. Smoliak, and W. D. Willms. 1990. *Distribution of nitrogen fractions in grazed and ungrazed fescue grassland Ah horizons.* J. Range Manage. 43: 6-9.
6. Dormaar, J. F., S. Smoliak, and W. D. Willms. 1990. *Soil chemical properties during succession from abandoned cropland to native range.* J. Range Manage. 43: 6-9.
7. Gould, W. D. 1982. *Denitrification in Alberta soils.* In L.J.L. Sears, K. K. Krogman, and T. G. Atkinson [eds.] *Research Highlights - 1981.* Agri. Can. Res. Sta., Lethbridge, Alta. pp. 67-68.
8. Heady, H. F. 1975. *Rangeland management.* McGraw-Hill Book Co., New York, N.Y.
9. Jenny, H. 1980. *The soil resource: Origin and behavior.* Springer-Verlag, New York, N.Y.
10. Johnston, A. 1961. *Comparison of lightly grazed and ungrazed range in the fescue grassland of southwestern Alberta.* Can. J. Plant Sci. 41: 615-622.
11. Johnston, A. 1962. *Effects of grazing intensity and cover on the water-intake rate of fescue grassland.* J. Range Manage. 15: 79-82.
12. Johnston, A., J. F. Dormaar, and S. Smoliak. 1971. *Long-term grazing effects on fescue grassland soils.* J. Range Manage. 24: 185-188.
13. Moss, E. H., and J. A. Campbell. 1947. *The fescue grassland of Alberta.* Can. J. Res. C 25: 209-227.
14. Nacth, M. A. 1988. *The impact of grazing on litter and hydrology in mixed prairie and fescue grassland ecosystems of Alberta.* Ph.D. thesis. Univ. Alta., Edmonton.
15. Neal, J. L. Jr. 1969. *Inhibition of nitrifying bacteria by grass and forb root extracts.* Can. J. Microbiol. 15: 633-635.
16. Reeves, B.O.K. 1978. *Bison killing in the southwestern Alberta Rockies.* Plains Anthropologist 23-82, pt. 2: 63-78.
17. Shantz, B. 1967. *Rodent-watershed relationships.* Project progr. Rpt. 85-5-5-132. Can. Wildlife Serv., Edmonton, Alta.
18. Stoddart, L. A., A. D. Smith, and T. W. Box. 1955. *Range management.* McGraw-Hill Book Co., New York, N.Y.
19. Thomas, A. S. 1960. *The tramping animal.* J. Brit. Grassland Soc. 15: 89-93.
20. Turner, G. T. 1973. *Effects of pocket gophers on the range.* In G. T. Turner, R. M. Hansen, V. H. Reid, H. P. Tietjen, and A. L. Ward [eds.] *Pocket gophers and Colorado mountain rangeland.* Bull. 554S. Colo. State Univ. Exp. Sta., Fort Collins. pp. 51-61.
21. Willms, W. D., J. F. Dormaar, and G. B. Schaalje. 1988. *Stability of grazed patches on rough fescue grasslands.* J. Range Manage. 41: 503-508.
22. Willms, W. D., S. Smoliak, and G. B. Schaalje. 1986. *Cattle weight gains in relation to stocking rate on rough fescue grassland.* J. Range Manage. 39: 182-187.
23. Willms, W. D., S. Smoliak, and J. F. Dormaar. 1985. *Effects of stocking rate on a rough fescue grassland vegetation.* J. Range Manage. 38: 220-225.
24. Wroe, R. A., M. G. Turnbull, S. Smoliak, and A. Johnston. 1981. *Guide to range condition and stocking rates for Alberta.* Alta. Energy and Natural Resources, Edmonton. □

The potential for LISA-type nitrogen use adjustments in mainstream U.S. agriculture

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ABSTRACT: Concern about environmental impacts of nitrogen (N) fertilizer use is increasing. Mainstream agriculture is dependent on N fertilizer, and use patterns are polluting water resources. A 5-cent tax on N fertilizer is shown to have three benefits. National N fertilizer use is estimated to decline about 10%. Use of legume-produced N increases, and crop use of N declines only 5%. A reduction in wasted legume-produced N equal to 2.5% of N application in the baseline occurs because of increased use of legumes and other crops in rotation. The N tax is not without costs. Soil erosion and pesticide use are estimated to increase 2.2 and 1.7%, respectively, in response to the tax.

BOTH the research community and the public have expressed growing concern about nonpoint-source pollution of water by nitrogen (N) fertilizer (*7, 11, 15, 22*). Farmers have increased crop production capacity by using manufactured N fertilizers (*1, 16*). Also, N fertilizer often has been applied beyond the levels removable by crop production. The result has been excess, leachable nitrate in the root zone, contaminating water supplies (*9, 15, 18*). Nitrogen contamination of water has been linked to human health risks, poisoning of livestock, and soil salinity (*12*). Various legislative bodies are considering policies for regulating nitrogen use (*23*).

There are several reasons farmers apply more N fertilizer than is removed by the crop. First, production practices, timing, and application methods may result in use of more N than is required to assure sufficient amounts in the right place at the right time for accelerated plant growth. Second, N fertilizer is relatively inexpensive, and farmers may apply excessive amounts to ensure against the income losses due to weather. Third, crop insurers may require high N application rates as a best management practice. Fourth, N-response research results and application recommendations may suggest unrealistic yield goals. Finally, crop-specific government commodity policies influence rotation choices, resulting in underuse of legume-produced N.

Information to support analyses of potential N use polices is limited. Nitrogen sales data are available at the county level. But data on the disposal or use of N by crop and management technique, by county, generally are not available. Potential responses of producers to alternative N regulations also are unknown. To fill this information gap, plant growth and economic interregional resource allocation/commodity production models can be combined to estimate N use. That is, use levels for N by crop, soil, and management technique and likely changes in response to a N use tax to alternative regulations can be estimated. Differential impacts of the N tax by region and producer type also can be estimated.

In this study, we estimated the effects of a 5-cent N tax to show low-input, sustainable-agriculture (LISA)-type management practice adjustments possible with conventional production technology. The approach used is not new. During the 1970s, when

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energy prices were increasing, similar evaluations were made to determine likely adjustments to N taxes or quotas (*10, 13, 18, 19, 20, 21*). Other, more theoretical papers have shown how a N tax could be derived to result in a closer matching of private and public interests (*4, 8*). Swanson (*18*) summarized the results of various studies of N use regulation by taxes and quotas.

The models

We used the Agricultural Resources Interregional Modeling System (ARIMS) (*2*) for our analysis. ARIMS is a national-level interregional linear programming model with activities representing average producer technology by region (105 for crop production and 31 for marketing and livestock production), land quality, and management practices. ARIMS was developed for the 1985 Resources Conservation Act appraisal and is based on the large-scale linear programming modeling systems historically used by the Center for Agricultural and Rural Development at Iowa State University. The solution of the model can be interpreted as estimating the equilibrium aggregate response of producers, given sufficient adjustment time, fixed commodity demands, and purchased inputs available at constant prices.

ARIMS estimates the overall N fertilization level for each crop, legume crop production, and substitution of livestock manure for purchased N. Production activities require either purchased inputs or inputs from internal production, for example, manufactured N fertilizer or manure from livestock. Also included are activities for livestock feeding and production, land conversion, and land idling. Regional commodity demands can be met by local production or by transportation of commodities produced in other regions. Three market regions serve as trade links to international markets.

ARIMS results are conditioned by fixed commodity demands, projected yield growth, the policy provisions of current agricultural legislation, and estimated market outcomes for 1990. These factors are taken from FAPRI (*5*) and U.S. Department of Agriculture (USDA) statistics. Production technology and environmental impact information for cropping and land use in ARIMS are derived largely from the erosion-productivity impact calculator (EPIC) (*14*).

For an area, soil type, year, and management technique, crop yields of each production activity are fixed, as are fertilizer requirements per unit of yield. Nitrogen use levels can change only as crop acreage and yields change as a result of changes in management techniques. For each cropping activity, crop yields are predetermined using FAPRI and USDA statistics and EPIC results (*14*). We used a Spillman-type yield function (*3, 6, 17*) to estimate N requirements, given the predetermined yields.

The 5-cent N tax was approximated by a price increase in each region. Yield and N levels were estimated from the 1990 baseline. Modifications in N use and yield implied by the Spillman estimates and the tax then were applied. In rotations including legume crops, the tax may lower the N use level to the point that legumes produce more N than is needed for the rotation. In that case, the application requirement is set to zero.

Regional prices for N vary in the United States. To illustrate the magnitude of the fertilizer price change from the 5% tax within ARIMS, a use-weighted N price was calculated. This weighted price increased from 22.5 to 27.5 cents per pound. On average, the approximate 25% increase in N price affected fertilizer use by about 5% (N application by 10%) and yields by 1 to 2% (Table 1). However, in aggregate, after the model accounted for possible interregional, crop rotation, and livestock production changes, the estimated aggregate percentage changes in yields were smaller.

Table 1. Yield and N use elasticities associated with model coefficients.*

	National Level Elasticities			
	Partial Effects			Full Model Effects†
Crop	Nitrogen Use/ Price of Nitrogen	Yield/ Nitrogen Application	Yield/ Price of Nitrogen	Output/ Price of Nitrogen
Barley	−0.36	0.22	−0.08	−1.2
Corn grain	−0.59	0.21	−0.12	−2.6
Corn silage	−0.68	0.14	−0.10	−1.1
Cotton	−0.24	0.26	−0.06	−0.2
Legume hay	−0.15	0.00	−0.00	−0.4
Nonlegume hay	−0.57	0.15	−0.09	−1.5
Oats	−0.47	0.20	−0.09	−0.7
Sorghum	−0.57	0.20	−0.11	−0.3
Sorghum silage	−1.08	0.07	−0.08	0.0
Soybeans	−0.13	0.04	−0.01	−0.1
Wheat	−0.36	0.21	−0.08	−0.4

*National averges for rainfed crops; the use-weighted N price increased from 22.5 to 27.5 cents/pound.
†National average yield change in response to the N tax after all endogenous adjustments.

Table 2. Percent change in fertilizer application due to the N tax (percent from baseline).

	Percent Change in Fertilizer Application					
	N		P		K	
Region	Total	Per acre	Total	Per acre	Total	Per acre
Northeast	5.8	−3.7	11.8	1.7	11.6	1.5
Appalachia	−7.9	−7.4	−3.8	−3.3	−4.9	−4.4
Southeast	−4.3	−4.0	−4.0	−3.8	−3.1	−2.8
Delta	−7.2	−8.8	−5.4	−7.0	−5.4	−7.0
Corn Belt	−9.8	−10.8	−4.2	−5.2	−4.5	−5.5
Lake States	−8.4	−8.4	−3.6	−3.6	−6.7	−6.7
Northern Plains	−13.2	−13.2	−11.1	−11.1	−11.8	−11.8
Southern Plains	−11.9	−11.9	−11.1	−11.0	−9.9	−9.8
Mountain States	−9.0	−9.3	−5.0	−5.3	−5.9	−6.2
Pacific	−5.4	−6.3	−2.2	−3.0	−2.2	−3.1
National	−9.4	−10.1	−3.4	−4.2	−5.9	−6.6
National baseline*	8,040.0	50.0	4,184.0	26.0	2,829.0	18.0

*Baseline quantities are thousands of tons.

Table 3. Regional change in crop production due to the N tax (percent from baseline).

	Crop Production Changes (%)								
Region	Barley	Corn Grain	Corn Silage	Cotton	Sorghum	Soybeans	Wheat	Legume Hay	Nonlegume Hay
Northeast	−6.9	13.8	45.7	0.0	−50.4	28.9	2.4	18.8	−1.5
Appalachia	16.2	−1.4	−18.7	−2.2	−1.4	−2.6	−3.6	10.7	−8.9
Southeast	−3.6	−2.0	0.0	−3.6	−4.4	0.2	−2.1	−3.1	−2.3
Delta	0.0	−4.3	0.0	14.3	2.0	−2.1	−2.7	1.5	−2.5
Corn Belt	8.7	−0.4	−100.0	27.4	−5.7	0.1	1.2	3.8	−8.3
Lake States	2.0	−0.6	0.0	0.0	−1.6	−2.1	−3.4	3.5	−2.5
Northern Plains	−0.9	−4.7	0.0	0.0	4.4	−4.2	0.0	−23.9	2.1
Southern Plains	−2.1	15.7	0.0	−5.6	0.0	31.1	−0.8	−0.4	−5.0
Mountain States	0.3	0.3	−1.0	8.5	−2.0	−2.9	−0.4	−0.0	−3.2
Pacific	−2.1	−10.3	9.8	−3.8	−4.0	0.0	3.3	0.6	−1.7
National	0.0	−0.0	9.0	0.0	0.0	0.2	0.0	2.4	−2.6

Results

Herein, we report only aggregate results from the experiment. The ARIMS results

depend partly upon the specified market demand levels and rigid acreage allocations implied by commodity program parameters. These conditioning factors, together with the aggregate nature of the model, may give adjustments different from those that would be expected for a single farm or region. In short, the policy impacts estimated by ARIMS are intended to be national and interregional indicators, and they must be interpreted within the context of the model.

Fertilizer use. In ARIMS, aggregate N use can vary by (1) changes in application level for an individual cropping activity; (2) changes in overall cropping mix, which must be reflected in livestock feed substitution because final demand composition is fixed; and (3) changes in management practices, such as crop rotations. For example, legumes can be substituted for nonlegumes, and crops with lower N requirements can be substituted in the overall crop mix. These changes can occur within and between regions. In particular, and important for the results presented, legumes can be grown in rotation with nonlegumes.

In ARIMS, animal-produced N is directly substitutable for purchased N. Thus, the substitution between produced and purchased N can result in avoiding the N tax with no implied change in total application. In some cases, the N available for leaching can be more than the reported application, when legumes produce more than the next crop in the rotation requires.

For the national 5-cent N tax, total and per-acre nitrogen applications (fertilizer and manure) by USDA production region declined between 4% and 13% compared to the baseline (Table 2). However, legume-produced N use increased and plant use of N declined by only one-half the reduction in purchased N application. National production of legumes increased only 2.5% (Table 3), indicating that about one-half of the substituted legume-produced N was already "in the system" but in rotations where it was not usable. These results can be seen by comparing plant nutrient application changes (columns one and three of table 2) and noting that in ARIMS crops are required to use N, phosphorous (P), and potassium (K) in fixed proportions. In summary, the use of N by crops was down about 5%, and there was an additional reduction of excess N in the system because of better use of legumes, equal to about one-half of the decline in purchased N application.

The N tax increased cropped acreage and fertilizer use in the Northeast, probably because of transportation costs and higher production costs for grain in other regions (Table 3). Total P and K changes for the Northeast were greater than for N, while per-acre changes were lower, indicating a substantial shift to legume-produced N (Table 2 and 3). In Appalachia, there was a shift to relatively more intensive cropping because per-acre N use dropped relatively less than total use (Table 2).

In the Southeast and the Delta, the tax had little impact on crop mix or management practice; all nutrients declined proportionately. In the Corn Belt, there was less intensive cropping because per-acre application declined more than total use, implying that more legumes were grown in rotation. The 10% decline in N use in this area was especially significant, given the heavy level of use in the baseline (Table 2).

The Lake States region showed a similar relative cropping intensity between the two ARIMS runs, in as much as per-acre and total fertilizer applications changes were nearly equal. The largest decreases in N application (about 12%) occurred in the Great Plains, with little change in either crop mix, management, or cropping intensity; implied crop acreages were similar to the base (Table 3). In the Mountain States, there also was a large decrease in N application (9%), along with a movement to less intensive cropping because per-acre quantities declined by more than the totals.

Nonnutrient input use. Different management practices involve alternative, relative proportions of the inputs. The N tax affected the use of other production factors (Table 4). At the national level, increased pesticide use (1.7%) was more than double the increased acreage (0.8%) and was one and one-half times the increase in machinery and labor (1.1%). In general, this implied shifts to more intensive cropping, with pesticides having a larger share of production costs in selected areas.

The increase in input use, particularly pesticides (12.9%), was dramatic in the Northeast. This pesticide use increase, accompanied by the N increase, indicates an environmentally negative impact of the fertilizer tax, suggesting consideration of more specialized taxes. Only in Appalachia and the Southeast did pesticide use decrease, and these decreases were exactly equal to cropped acreage declines. All other regions had higher rates of pesticide use per acre than before the N tax. In most regions pesticide use increased relative to machinery and labor, implying a move away from what is commonly understood to be low-input, sustainable agriculture for some land types.

Soil erosion impacts. The N tax resulted in increased soil erosion at the national level, both per acre (1.3%) and in total (2.2%) (Table 5). Lower yields, combined with fixed demands, imply more intensive cropping on more marginal land. In all but the Southern Plains, Mountain States, and Pacific States, wind erosion decreased because of the tax. Water erosion was up in all regions except Appalachia and the Southeast. These percentage changes were small in general compared to those reported for

Table 4. Percent changes in non-nutrient input use resulting from the N tax (percent from baseline).

	Change in Non-nutrient Inputs (%)			
Region	*Cropped Acres*	*Pesticides**	*Machinery**	*Labor**
Northeast	10.0	12.9	11.6	11.6
Appalachia	−0.5	−0.5	−0.1	0.2
Southeast	−0.3	−0.3	−0.5	−0.4
Delta	1.8	6.8	4.3	3.0
Corn Belt	1.1	1.5	1.4	1.2
Lake States	0.0	0.1	−0.1	0.2
Northern Plains	0.0	0.4	−0.3	−0.2
Southern Plains	−0.1	0.5	0.2	0.2
Mountain States	0.3	1.1	0.5	0.7
Pacific	0.7	2.3	0.6	0.2
National	0.8	1.7	1.1	1.1

*Expenditure changes.

Table 5. Soil erosion impacts resulting from the N tax (percent from baseline).

	Soil Erosion Impacts					
	Per Acre			*Total*		
Region	*Water*	*Wind*	*Total*	*Water*	*Wind*	*Total*
Northeast	16.3	−9.5	15.0	29.4	−0.7	27.8
Appalachia	0.0	−0.7	−0.0	−0.5	−1.3	−0.6
Southeast	−0.5	−0.9	−0.5	−0.9	−1.2	−0.9
Delta	0.7	−1.0	0.5	2.8	1.1	2.6
Corn Belt	2.9	−1.2	2.2	4.0	−0.1	3.3
Lake States	1.6	−0.7	0.6	1.6	−0.6	0.7
Northern Plains	2.7	−1.1	0.2	2.7	−1.2	0.1
Southern Plains	2.1	2.9	2.7	2.0	2.8	2.6
Mountain States	0.2	0.2	0.2	0.6	0.6	0.6
Pacific	3.2	1.0	2.1	4.5	2.3	3.4
National	3.0	−0.3	1.3	3.9	0.6	2.2

cropped land (Table 4) and fertilizer use (Table 2).

Regional crop production patterns. Regional shifts in crop production due to the tax were large (Table 3). At the national level, only commodities used as feed are allowed to change because final demands in ARIMS are fixed. But regional distributions of crop production can change. For the nation, legume hay was substituted for nonlegume hay, soybeans increased by 0.2%, and corn silage increased by 9.0%.

Barley was substituted for corn silage in Appalachia (16.2 for −18.7%), in the Corn Belt (8.7 for −100.0%), and to lesser extent in the Lake States and Mountain States. Corn silage was substituted for barley in the Northeast (45.7 for −6.9%) and at lower levels in the Southeast, Northern Plains and Southern Plains, and Pacific areas. These changes correlate to some extent with the livestock production changes (Table 6). The Northeast region showed the largest crop mix impacts. The Northern Plains and Mountain States both had a decrease in total acreage in legumes; however, the nutrient requirement impacts (Table 2) indicate more legume-produced N. Thus, crop rotation changes occurred as a result of the tax.

Livestock production due to nitrogen tax. At the national level, there were no changes in livestock production because final demands were unchanged from the baseline (Table 6). Regional shifts in production, however, were large. There was a general shift in cattle and fed-beef production from the Southern Plains to the Corn Belt. The percentage changes (Table 6) were modest, but actual numbers were large because these regions had a major share of national production in the baseline.

The greatest regional shifts were in pork production, with percentage gains for the Northeast (19.9%) and Lake States (27.3%) and losses in Appalachia (−28.9%), the Southern Plains (−91.8%), and Mountain States (−23.7%). Dairy production and grass-fed beef shifted among regions the least. Cattle (cow-calf) and grain-fed beef production recorded major shifts.

Producer cost and income. We evaluated changes in producer costs and income due to the N tax by comparing changes in total production cost with changes in estimated total imputed revenue (Table 7). The baseline or base run was again the reference point.

At the national level, crop producers gained at the expense of livestock producers. Total costs increased 0.8%, while total revenue increased 2.2%. For livestock producers, a 0.7% revenue decrease offset the small decrease in production costs. Crop producers gained 5.1% in imputed revenues, while production costs increased only 1.3%. The Appalachian region was negatively impacted the most, as indicated by the balance of cost and revenue changes, while the Lake States, Northern Plains, Southern Plains, and Mountain States all gained.

Conclusions

Results from the analysis with ARIMS indicate a N tax of reasonable size has an impact on fertilizer use even if opportunities for response were restricted to existing production technologies. Although the estimated impacts of the N tax from ARIMS were fairly small, they were larger than found in other studies (*18*). Still, the results are in general agreement with the idea that with current production technology farmers are not likely to be highly responsive to price in fertilizer usage. However, despite the limitations for substitution in N use in ARIMS, considerable flexibility in accommodating to the tax is indicated for mainstream U.S. agricultural technologies. The policy question is how to design measures that can take advantage of this potential flexibility.

The ARIMS solution shows that applied commercial fertilizer is not the sole problem leading to current levels of water contamination. With present commodity policy, farmers are led to crop rotation sequences in which legume-produced N is underused. According to the analysis, policies affecting rotation choices can have large impacts on N use. The fertilizer tax is one such policy, but it can result in the substitution of other inputs, implying greater chemical use and in some cases increased erosion levels.

Estimated national impacts of the N tax experiment were relatively small. However, the impacts on individual farmers and regions may be large. For example, imposing a blanket national tax may unfairly penalize producers in those areas of the nation where water contamination problems are not severe and may inadequately address significant problems elsewhere. Crop producers generally benefit from input taxes because final demands are relatively inelastic. Increases in marginal production costs exceed the increase in average costs, and revenue increases exceed cost increases. However, this result is highly conditioned by the cost minimization structure implicit in the ARIMS specification. That is, with supported commodity prices, producers may in reality experience only the cost increases estimated by ARIMS because increased market prices would in large part only reduce government costs.

Table 6. Regional changes in livestock production due to the N tax (percent from baseline).

	Livestock Changes (%)				
				Beef	
Region	Pork	Dairy	Cattle	Grain	Grass
Northeast	19.9	0.3	0.3	241.5	0.2
Appalachia	−28.9	0.2	8.1	241.5	2.2
Southeast	0.0	−0.0	−0.4	0.0	−2.1
Delta	0.1	0.0	0.2	−1.0	0.8
Corn Belt	−0.5	0.8	5.5	1.4	3.1
Lake States	27.3	−2.1	−0.8	1.3	−1.8
Northern Plains	1.0	−3.5	1.7	−4.3	2.7
Southern Plains	−91.8	0.1	−6.5	−4.6	−2.9
Mountain States	−23.7	2.3	0.4	−1.7	0.6
Pacific	0.0	0.0	0.5	1.3	0.5
National	−0.0	−0.0	−0.0	0.0	0.0

Table 7. Percentage change in producer costs and returns due to the N tax (percent from baseline).

	Change in Producer Costs and Returns (%)					
	Crops		Livestock		Total	
Region	Cost	Returns	Cost	Returns	Cost	Returns
Northeast	13.1	18.3	0.8	0.5	6.0	6.3
Appalachia	−0.1	1.5	0.6	−2.7	0.2	−0.4
Southeast	−0.7	0.9	−0.3	−0.9	−0.5	−0.2
Delta	3.6	5.0	0.0	−1.6	2.1	2.1
Corn Belt	0.9	3.9	0.8	−0.2	0.9	1.9
Lake States	1.6	5.3	4.0	2.4	1.6	3.7
Northern Plains	−0.0	5.4	0.2	−1.9	0.0	2.7
Southern Plains	1.3	4.3	−5.1	−4.0	−1.8	2.5
Mountain States	0.9	7.9	0.0	−1.8	0.6	2.7
Pacific	0.5	6.5	0.4	0.0	0.4	2.0
National	1.3	5.1	−0.0	−0.7	0.8	2.2

REFERENCES CITED

1. Delwiche, C. C. 1970. *The nitrogen cycle.* In *The Biosphere.* W. H. Freeman and Co. San Francisco, Calif. pp. 71-80.
2. English, Burton C., Elwin G. Smith, Jay D. Atwood, George Oamek and Stanley R. Johnson. 1989. *Resource Conservation Act analysis: An overview of the CARD agricultural resource interregional modeling system.* CARD Tech.

Rpt. 89-TR11. Center for Agr. and Rural Devel., State Univ., Ames.
3. English, Burton C., Klaus F. Alt, and Earl O. Heady. 1982. *A documentation of the Resources Conservation Act's assessment model of regional agricultural production, land and water use, and soil loss.* CARD Rpt. 107T. Center for Agr. and Rural Develop., Iowa State Univ., Ames.
4. Feinerman, Eli, E. Kwan Choi, and Stanley R. Johnson. 1990. *Uncertainty and split nitrogen application in corn production.* Am. J. Agr. Econ. (in press).
5. Food and Agricultural Policy Research Institute. 1988. *FAPRI ten-year international agricultural outlook. Summary and tables, March.* Center Agr. and Rural Develop., Iowa State Univ., Ames.
6. Griffin, Ronald C., John M. Montgomery and M. Edward Rister. 1987. *Selecting functional form in production function analysis.* West. J. Agr. Econ. 12(2): 216-227.
7. Hargrove, W. L. 1988. *Cropping strategies for efficient use of water and nitrogen.* Spec. Publ. No. 51. Am. Soc. Agron., Madison, Wisc.
8. Horner, Gerald L. 1975. *Internalizing agricultural nitrogen pollution externalities: A case study.* Am. J. Agr. Econ. (February): 33-39.
9. Keeney, D. R. 1983. *Transformation and transport of nitrogen.* In Frank W. Schaller and George W. Bailey [eds.] *Agricultural Management and Groundwater Quality.* Iowa State Univ. Press, Ames. pp. 48-64.
10. Kramer, Randall A., William T. McSweeney, Waldon R. Kerns, and Robert W. Stavros. 1984. *An evaluation of alternative policies for controlling agricultural nonpoint source pollution.* Water Resources Bull. 20(6): 841-846.
11. Nielsen, Donald R., and J. G. MacDonald. 1978. *Nitrogen in the environment.* Academic Press, New York, N.Y.
12. Nielsen, Elizabeth B., and Linda K. Lee. 1987. *The magnitude and costs of groundwater contamination from agricultural chemicals: A national perspective.* Agr. Econ. Rpt. No. 576. Econ. Res. Serv. U.S. Dept. Agr., Washington, D.C.
13. Palmini, Dennis J. 1982. *The secondary impact of nonpoint-pollution controls: A linear programming-input/output analysis.* J. Environ. Econ. and Man. 9: 263-278.
14. Putman, John W., and Paul T. Dyke. 1987. *The erosion-productivity impact calculator as formulated for the Resource Conservation Act appraisal.* No. AGES861204. Econ. Res. Serv., U.S. Dept. Agr., Washington, D.C.
15. Schaller, Frank W., and George W. Bailey, [eds.] 1983. *Agricultural management and water quality.* Iowa State Univ. Press, Ames.
16. Sprent, Janet I. 1987. *The ecology of the nitrogen cycle.* Cambridge Univ. Press, New York, N.Y.
17. Stoecker, Art. 1974. *A quadratic programming model of U.S. agriculture in 1980.* Ph.D. diss. Iowa State Univ., Ames.
18. Swanson, E. R. 1982. *Economic implications of controls on nitrogen fertilizer use.* In *Nitrogen in Agricultural Soils.* Agron. Monog. No. 22. Am. Soc. Agron., Madison, Wisc.
19. Taylor, C. Robert, and Klaus K. Frohberg. 1977. *The welfare effects of erosion controls, banning pesticides, and limiting fertilizer application in the Corn Belt.* Am. J. Agr. Econ. 59: 25-36.
20. Thomas, Dennis L., and Earl O. Heady. 1977. *American agriculture in 1980 under a fertilizer allocation system.* Center for Agr. and Rural Develop., Iowa State Univ., Ames.
21. Walker, Jr., M. E., and E. R. Swanson. 1974. *Economic effects of a total farm nitrogen balance approch to reduction of potential nitrate pollution.* Ill. Agr. Econ. (July): 21-27.
22. Wilson, J. R. 1988. *Advances in nitrogen cycling in agricultural ecosystems.* Proc., Symp. on Advances in N Cycling in Agr. Ecosystems, C.A.B. International, Wallingford, Eng.
23. Wise, Sherry, and Stanley R. Johnson. 1989. *A comparative analysis of state regulations for the use of agriculture chemicals.* In Nancy Bockstael and Richard Just [eds.] *Commodity and Resource Policies in Agricultural Systems.* Springer-Verlag, Berlin, Germany. □

Reducing field losses of nitrogen: Is erosion control enough?

Fritz M. Roka, Richard A. Levins, Billy V. Lessley, and William L. Magette

ABSTRACT: Reducing nitrogen (N) losses in surface runoff from a representative farm on the Upper Eastern Shore of Maryland is shown to be compatible with traditional methods of soil erosion control. Cropping adjustments that reduced erosion also reduced field losses of surface N. Analysis of potential methods to reduce nitrate percolation losses, however, showed that large reductions in nitrate percolation losses were achieved by shifting from corn to soybeans and from no-till practices to conventional tillage management, thereby increasing surface losses of soil and N.

IMPROVED water quality often is cited as one of the benefits of soil conservation programs (*8*). For example, the Conservation Reserve Program has been justified partly by the positive effects it will have on water quality (*3*). The relationship between erosion control and water quality is straightforward if sediment is a principal water pollutant. If it is not, water quality benefits of erosion control become less clear.

Knisel and associates suggested that soil conservation and water quality protection can be contradictory goals (*5*). They argued that controlling surface water movement reduces surface losses of pollutants but can simultaneously increase groundwater pollution resulting from increased percolation losses. Such cases are likely when sediment is not the principal water pollutant. For example, nitrogen (N) is considered the leading nonpoint-source agricultural pollutant in Maryland (*6*). State officials have endorsed a public policy goal to reduce nonpoint N loadings to the Chesapeake Bay 40% by the year 2000 (*1*). Because a portion of N field losses is transported with detached sediment, a side benefit of soil erosion control could be a reduction in sediment-bound N. However, because nitrate salts are water soluble, N can move independently of soil, either with surface runoff or in water percolating into groundwater.

Herein, we examine the economic and environmental trade-offs between controlling surface and percolation losses of N for a typical cash grain farm on the Upper Eastern Shore of Maryland. Results indicate that cropping adjustments that control one pathway of N transport may exacerbate others.

Study methods

A 324-ha (800-acre) cash grain farm was specified as representative of agricultural conditions on the Upper Eastern Shore, which is located in the mid-Atlantic Coastal Plain. We assumed the farm was planted to a combination of corn grain, soybeans, and wheat. The farm operator could use conventional tillage, no-till, winter cover crops after row crops, or idle cropland as economic conditions and environmental restrictions warranted.

The farm was comprised of four soil conditions that represented two soil textures and two average field slopes: 150 ha (370 acres) of Sassafras sandy loam on a 3.5% slope, 22 ha (55 acres) of Sassafras sandy loam on a 7.5% slope, 128 ha (315 acres) of Matapeake silt loam on a 3.5% slope, and 24 ha (60 acres) of Matapeake silt loam on a 7.5% slope. We assumed soils were well-drained and had a rooting zone of 91 cm (36 inches). Specific hectarages of each soil type roughly correspond to area proportions of the respective soil types on the Upper Eastern Shore of Maryland (*9*).

We developed crop budgets showing returns to land, fixed capital, and management for 60 crop-management-soil combinations. Variable production and machinery costs, together with estimated labor requirements for each crop system, were taken from Roka (*9*). Market and input prices were chosen as representative of 1985-1986 market conditions. Crop returns assumed market prices of \$0.11, \$0.12, and \$0.22/kg (\$2.70, \$3.05, and \$5.85 per bushel) for corn grain, wheat

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and soybeans, respectively.

We developed crop yields from yield information in county soil surveys (*11, 12, 13, 14, 15*) to determine relative differences in crop yields among soil categories. These relative differences were applied to regional production averages for 1981-1985 to obtain yields for the representative farm (*9*). For field slopes of 3.5%, corn yields were budgeted to be 7,850 kg/ha (125 bushels/acre) and 7,220 kg/ha (115 bushels/acre) on Matapeake silt loam and Sassafras sandy loam, respectively. Wheat and soybean yields were 3,360 kg/ha (50 bushels/acre) and 2,070 kg/ha (33 bushels/acre) for both soil types. At 7.5% field slopes, crop yields declined. On Matapeake silt loam and Sassafras sandy loam, corn yields dropped to 6,900 kg/ha (110 bushels/acre) and 6,590 kg/ha (105 bushels/acre), respectively. Wheat and soybean yields declined to 3,025 kg/ha (45 bushels/acre) and 1,950 kg/ha (29 bushels/acre), respectively.

Nitrogen fertilization rates for corn and wheat followed current recommendations of the University of Maryland Agronomy Department: 75 kg/kg and 67 kg/kg (1.2 pounds and 1.0 pound/bushel) of expected yield, respectively. Soybeans did not receive N fertilization. Methods of N application also followed production practices of growers on the Upper Eastern Shore. Nitrogen was split in three applications for corn with 65% of the total amount being injected as sidedressing in mid-June. Nitrogen fertilization for wheat was split in two applications. Ten percent of the total N for wheat was drilled during fall planting; the balance was broadcast in early March.

We used the CREAMS (Chemicals, Runoff and Erosion from Agricultural Management Systems) model (*4*) to simulate average annual per hectare losses of soil, surface N, and nitrate percolation occurring from the 60 budgeted farm activities. CREAMS is a comparative simulation model that evaluates relative changes in pollutant losses among alternative management systems for specific field conditions. Parameters describing hydrology, erosion, and chemical components were taken from the CREAMS user's guide (*10*) and modified as necessary to match climatic, agricultural, and soil conditions on the Upper Eastern Shore. We based simulation on daily rainfall records collected at the Wye Research and Education Center, Queenstown, Maryland. Simulations covered an 11-year period, from January 1, 1976, to December 31, 1986. Using hydrology output and assuming uniform slope configuration, erosion and nutrient components of CREAMS simulated "edge-of-field" losses of soil, surface N, and nitrate percolation by soil type and crop system.

Table 1: Annual CREAMS-simulated runoff and percolation volumes for conventionally tilled corn on Matapeake silt loam and Sassafras sandy loam, 3.5% slope.

Year	Rainfall	Silt Loam		Sandy Loam	
		Runoff	Percolation	Runoff	Percolation
		cm/yr			
1977	89.9	5.3	3.1	3.6	18.0
1978	116.1	13.2	22.9	8.9	33.0
1979	136.1	12.5	24.1	7.1	42.2
1980	91.2	4.3	10.7	3.1	14.5
1981	101.1	5.1	0.3	3.6	15.0
1982	112.5	11.9	11.7	8.4	31.0
1983	123.2	16.0	22.1	10.9	39.9
1984	102.9	5.8	21.6	3.1	28.4
1985	89.4	6.1	0.0	4.6	8.6
1986	78.0	3.1	1.8	2.0	10.7
Annual Average	102.6	8.3	11.7	5.3	23.9

Here, our analyses of farm-level responses to reductions in soil or N field losses began with a behavioral assumption that production decisions corresponded with a farm operator's goal to increase profit. Following an approach taken by Crowder and associates (*2*), a linear programming model merged crop budget data with CREAMS data. The linear programming model (*9*) determined optimal crop combinations under soil loss and nitrate percolation controls that maximized farm returns subject to constraints on land and total hours available for field labor per period.

We established a farm base by solving the linear programming model without binding pollution constraints. The base represented crop combinations that the operator would choose if his/her sole interest was to maximize farm income. The farm operator's response to limits on erosion and nitrate percolation were simulated by solving the model separately for certain reduced levels of soil erosion and nitrate percolation found in the base solution. We then compared income and field losses of soil, surface N, and nitrate percolation with base values.

Results

CREAMS simulations vs. monitored data. We did not "calibrate" the CREAMS model to match existing data. Nor were large amounts of data available with which to judge the validity of CREAMS predictions for all cropping systems. However, a limited amount of data collected at two sites on the Upper Eastern Shore indicated that the model did make reasonable predictions of both water and pollutant movement.

Average annual precipitation for the study area during the simulation period (1976-1986) was 101/cm (40 inches); this precipitation was distributed fairly evenly throughout the year. Over the last 5 years at the sites from which physical data were obtained as CREAMS input for this study, annual precipitation was below average, ranging from 60% to 100% of average precipitation for the simulation period.

Runoff measured at the Wye Research and Education Center (Mattapex silt loam) and the Indiantown Demonstration Farm (Sassafras sandy loam) has been low. Since 1984, when monitoring began at these sites, runoff volume from corn production systems has ranged from 4.3 cm/yr (1.7 inches/year) to 11 cm/yr (4.4 inches/year) on Mattapex silt loam soil and from 1.8 cm/yr (0.7 inches/year) to 4.3 cm/yr (1.7 inches/year) on Sassafras sandy loam soil (*16* and unpublished data, William L. Maggette). For conventional and no-till corn systems, CREAMS prediction of annual runoff by soil texture is within the range of measured values. For example, table 1 shows these values for conventionally tilled corn.

Recharge to groundwater (leaching) ranges from 25.4 to 63.5 cm/yr (10 to 25 inches/year) in the mid-Atlantic Coastal Plain (*17*). Recharge generally occurs after crops have been harvested in the fall (mid- to late-October) (*16*). Under conventional corn production systems on Mattapex silt loam soils, recharge ranges from an estimated 15 to 20 cm/yr (6 to 8 inches/year) (*16*). Simulated percolation volumes (Table 1) are close to these values. We also believe distribution of simulated percolation volumes were fairly representative of observed distributions.

Corresponding to low runoff volumes, surface losses of sediment and N on monitored sites were low (*16* and unpublished data, William L. Magette). Erosion rates on conventionally tilled cornfields on either site were below 2.24 t/ha (1 ton/acre). Sediment losses from conventionally tilled soybean sites on the Sassafras sandy loam soil were 0.02 t/ha (0.01 ton/acre) in 1987. Of surface N losses measured from conventionally tilled corn and soybean systems, most were sediment-bound: 70% for corn and 60% for soybeans (unpublished data, William L. Magette).

Table 2 provides an example of the CREAMS output for all crop systems on Sassafras sandy loam soil on a 3.5% slope. For the other soil types, ranking of crop sys-

tems according to the magnitude of field losses remained consistent with the ordering in table 2. Runoff and percolation volumes differed by soil texture. There was greater surface runoff on silt loam soils than on sandy loam soils, but percolation was lower on the silt loam soil. For any given soil texture, simulated runoff and percolation volumes were equal for field slopes of 3.5% and 7.5%. As a result, erosion rates were greatest from silt loam soils on a 7.5% slope; nitrate percolation losses were highest on sandy loam soils.

CREAMS generally tended to predict sediment losses that were higher than those observed in Maryland field studies. In part, predicted N losses were high because CREAMS correctly predicted that N losses were mostly sediment-bound. It appeared that the predictions were consistent from one system to another, such that relative comparisons would be reasonable.

Economic simulations. In addition to field losses simulated by CREAMS, table 2 shows annual per-hectare returns to land, fixed capital, and management by crop and tillage system for Sassafras sandy loam soil on a 3.5% slope. For other soil types considered, the relative ranking of crop systems by returns remained consistent with the ordering in table 2. Because of higher potential corn yields, level silt loam soils produced higher returns than sandy loam soils on steeper field slopes.

The base solution indicated that no-till corn was the most profitable crop. Of the 324 total hectares (800 acre), 174 ha (430 acres), were planted to continuous corn 132 ha (325 acres) were rotated between no-till corn and no-till soybeans, and the remaining 18 ha (45 acres) were planted to continuous no-till soybeans. Farm returns averaged $420/ha ($170/acre). Average annual per-hectare losses of soil, surface N, and nitrate percolation were 2.24 metric tons (1.0 ton), 1.7 kg (3.8 pounds), and 6.1 kg (13.4 pounds), respectively.

Figure 1 illustrates crop adjustments that occurred when soil erosion under base conditions was reduced 20% and 40%. At both levels of reduction, no-till management was retained. Cropping systems shifted from soybeans to a combination of corn and wheat. In addition, the hectarage of winter cover crops and idle land increased.

Table 3 summarizes levels of unconstrained pollutants, that is, surface N and nitrate percolation, as soil losses were reduced. About 90% of total surface N losses were simulated by CREAMS to be sediment-bound. Consequently, levels of surface N losses changed directly with soil losses. Mass of nitrate percolation losses, however, increased as surface N and soil losses declined. CREAMS-simulated percolation losses from corn and wheat systems were higher relative to soybean systems. This was due to the occurrence of leaching soon after fertilization (7).

Crop management strategies that were intended to control nitrate percolation were quite different from strategies that controlled soil erosion. Figure 2 shows crop adjustments as base nitrate percolation losses were reduced 20% and 40%. Several shifts in cropping patterns occured simultaneously. Conventional tillage replaced no-till management, and corn acreage was displaced by soybeans and wheat/soybeans in double-cropping. The net effect of these cropping shifts was an increase in surface losses of N and soil when compared to erosion control strategies (Table 3).

Table 4 shows farm returns when soil or nitrate pecolation was reduced 20% and 40%. Farm income fell by a greater amount under nitrate percolation control than under soil erosion control. Table 4 also compares unit costs of reducing predicted surface N losses with unit costs of reducing predicted nitrate percolation losses. We determined unit costs by dividing the change in farm income by the change in N field-loss level. Reducing soil loss 40% decreased farm income $19.75/ha ($8/acre) and reduced surface N losses by 1.45 kg/ha (1.3 pounds/acre). Unit cost of surface N reduction with soil erosion controls was $5.50/kg ($6.15/pound) of surface N. Decreasing nitrate percolation 40% lowered farm income $32/ha ($13/acre) and nitrate percolation losses 5.9 kg/ha (5.3 pounds/acre). Unit

Table 2: Average annual returns and CREAMS-simulated field losses of soil, surface N, and nitrate percolation on Sassafras sandy loam soil, 3.5% slope.

		Field Losses		
Crop Systems	*Returns ($/ha)*	*Soil (t/ha)*	*Surface N (kg/ha)*	*Percolated N (kg/ha)*
Conventional tillage				
Corn-corn	433.90	4.5	6.5	23.4
Corn-wheat/soybeans	420.80	3.4	4.5	13.3
Corn + wheat cover	401.80	3.4	4.4	17.3
Corn-soybeans	361.50	4.9	6.9	13.3
Corn-wheat (clover)	304.20	2.9	3.1	28.5
Soybeans-soybeans	280.20	5.4	7.4	9.9
Soybeans + wheat cover	248.80	3.6	5.0	7.1
No-till				
Corn-corn	445.50	1.1	2.0	24.3
Corn-wheat/soybeans	424.00	0.5	1.6	13.7
Corn + wheat cover	413.90	0.7	1.2	17.6
Corn-soybeans	367.90	0.9	3.0	13.6
Corn-wheat (clover)	302.40	0.5	0.7	29.3
Soybeans-soybeans	281.90	3.6	5.3	10.2
Soybeans + wheat cover	249.30	0.9	1.5	7.3
Idle land	−20.00	0.5	0.6	4.6

Table 3: Summary of field losses under base and selected soil and percolation reduction plans.

	Field Losses by Plan		
		Reduction Plans	
Pollutants	*Base*	*20%*	*40%*
Controlled soil erosion			
Losses (t/ha)	2.2	1.8	1.3
Other associated losses			
Surface N (kg/ha)	4.3	3.5	2.8
Nitrate percolation (kg/ha)	15.0	15.4	16.7
Controlled nitrate percolation			
Losses (kg/ha)	15.0	12.1	9.1
Other associated losses:			
Surface N (kg/ha)	4.3	5.8	9.1
Soil erosion (t/ha)	2.2	3.4	6.1

Table 4: Summary of farm returns and unit cost of N reduction under soil and percolation controls.

	Returns and Costs by Plan		
		Reduction Plans	
Pollutants	*Base*	*20%*	*40%*
Controlled soil loss plan			
Farm returns ($/ha)	420.00	412.70	400.20
Unit cost of reduced surface nitrogen ($/kg)	—	1.59	2.28
Controlled nitrate percolation plan			
Farm returns ($/ha)	420.00	407.70	387.90
Unit cost of reduced nitrate percolation ($/kg)	—	0.71	0.91

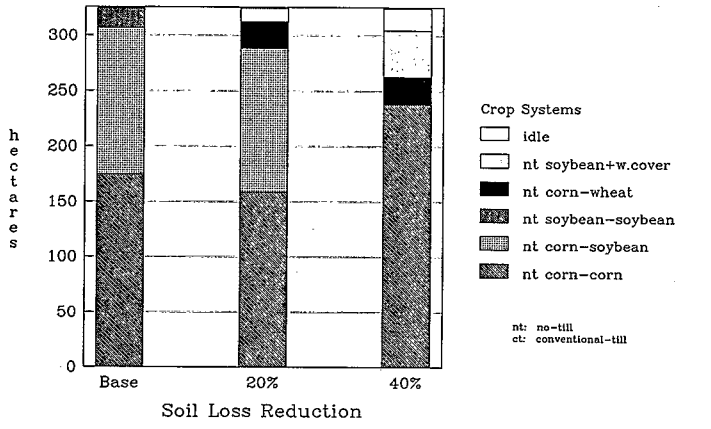

Figure 1. Crop adjustments as soil erosion under base condition is reduced 20% and 40%.

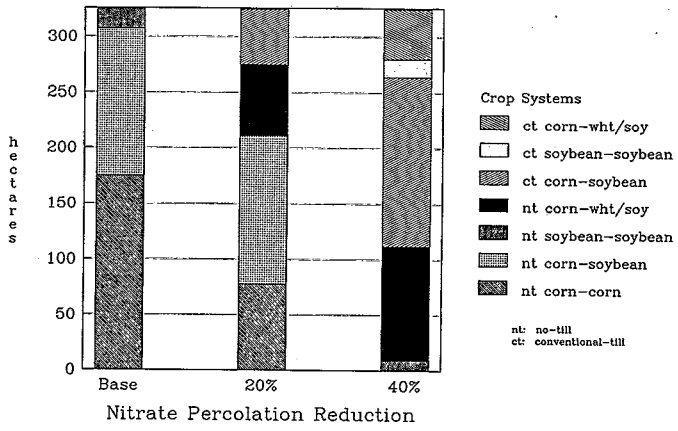

Figure 2. Crop adjustments as nitrate percolation under base condition is reduced 20% and 40%.

cost equalled $2.18/kg ($2.45/pound) of nitrate percolation reduced.

Conclusions

The control of agricultural nonpoint-source pollution is complicated by the variety of possible pollutants, pathways of movement, and interactions among crops and management practices over varying soil conditions. Our simulation results indicate that reducing agricultural nonpoint-source pollution would require flexible control guidelines that should be tailored to water quality problems in a specific site or region, for example, control of surface or subsurface N losses. Relying only on erosion control programs to combat water quality problems could be inefficient or counterproductive if improved water quality depends upon controlling subsurface N losses.

Reducing surface N runoff for a representative farm on the Upper Eastern Shore of Maryland proved to be compatible with traditional methods of controlling soil erosion. Cropping adjustments that reduced erosion rates also reduced field losses of surface N. Planting winter cover crops and adopting no-till management practices were effective in reducing surface losses. However, as predicted by the CREAMS model, resulting simulated nitrate percolation losses were greater, suggesting a trade-off between surface and subsurface N control.

The importance of making trade-offs between controlling movement of surface and subsurface pollutants was reemphasized when nitrate percolation losses were reduced. Large decreases in nitrate percolation losses were achieved by shifting from corn to soybeans and from no-till to conventional tillage management, thereby increasing surface losses of soil and N.

Any trade-off between controlling surface and subsurface pollutant movement implies that knowledge of *why* water quality is deteriorating, for example, N enrichment or sedimentation, is not sufficient. It is also necessary to know *how* water quality is deteriorating, for example, surface or subsurface pathways. Larger income reductions but lower unit costs of controlling nitrate percolation suggest that the pathways of N losses from agricultural systems need to be assessed accurately. The risk of incorrectly assessing the relative contribution of pollutant loadings from surface and subsurface sources would, at best, cause misallocation of public funds and, at worst, accelerate the deterioration of water quality.

REFERENCES CITED

1. Chesapeake Bay Program. 1988. *Draft baywide nutrient reduction strategy: Nutrient task force group agreement committee report.* U.S. Environ. Protection Agency Chesapeake Bay Liaison Off., Annapolis, Md.
2. Crowder, B.M., C. E. Young, D. J. Epp, J. G. Beierlein, H. B. Pionke, and E. J. Partenheimer. 1984. *The effects on farm income of constraining soil and plant nutrient losses: An application of the CREAMS simulation model.* Bull. 850. Penn. State Univ. Agr. Exp. Sta., University Park.
3. Gianessi, L. P., H. M. Peskin, P. Crosson, and C. Puffer. 1986. *Nonpoint-source pollution: Are cropland controls the answer?"* J. Soil and Water Cons. 41(5): 215-218.
4. Knisel, W. G., ed. 1980. *CREAMS: A field scale model for chemicals, runoff and erosion from agricultural management systems.* Cons. Res. Rpt. No. 26. Agr. Res. Serv., U.S. Dept. Agr., Washington, D.C.
5. Knisel, W. G., R. A. Leonard, and E. B. Oswald. 1982. *Nonpoint-source pollution control: A resource conservation perspective.* J. Soil and Water Cons. 37(2): 196-199.
6. Magette, W. L., and R. A. Weismiller. 1984. *Agriculture and the bay.* Fact Sheet 387. Univ. Md. Coop. Ext. Serv., College Park.
7. Magette, W. L., F. M. Roka, B. V. Lessley, and A. Shirmohammadi. 1988. *CREAMS as a tool for targeting AG BMP cost-sharing monies: Pollutant identification.* Paper 88-2078. Am. Soc. Agr. Eng., St. Joseph, Mich.
8. Ogg, C. W., and H. B. Pionke. 1986. *Water quality and new farm policy initiatives.* J. Soil and Water Cons. 41(1): 85-88.
9. Roka, Fritz M. 1988. *Economic evaluation of controlling field losses of selected agricultural pollutants.* M.S. thesis. Dept. Agr. and Resource Econ., Univ. Md., College Park.
10. Soil Conservation Service. 1984. *User's guide for the CREAMS computer model.* TR-72. U.S. Dept. Agr., Washington, D.C.
11. Soil Conservation Service and the Maryland Agricultural Experiment Station. 1964. *Soil survey of Caroline County, Maryland.* U.S. Dept. Agr., Washington, D.C.
12. Soil Conservation Service and the Maryland Agricultural Experiment Station. 1966. *Soil survey of Queen Anne's County, Maryland.* U.S. Dept. Agr., Washington, D.C.
13. Soil Conservation Service and the Maryland Agricultural Experiment Station. 1970. *Soil survey of Talbot County, Maryland.* U.S. Dept. Agr., Washington, D.C.
14. Soil Conservation Service and the Maryland Agricultural Experiment Station. 1973. *Soil survey of Cecil County, Maryland.* U.S. Dept. Agr., Washington, D.C.
15. Soil Conservation Service and the Maryland Agricultural Experiment Station. 1982. *Soil survey of Kent County, Maryland.* U.S. Dept. Agr., Washington, D.C.
16. Staver, K. W., R. B. Brinsfield, and W. L. Magette. 1988. *Nitrogen export from Atlantic Coastal Plain Soils.* Paper 88-2040. Am. Soc. Agr. Eng., St. Joseph, Mich.
17. Sun, R. J., ed. 1986. *Regional aquifer-system analysis program of the U.S. Geological Survey: Summary of projects, 1978-84. Circ.* 1002. U.S. Geol. Surv., Reston, Va. □

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Simulated effects of rapeseed production alternatives on pollution potential in the Georgia Coastal Plain

D. L. Thomas, M. C. Smith, R. A. Leonard, and F.J.K. daSilva

ABSTRACT: Long-term model simulations have the potential for economical evaluation of alternative management practice effects on pollutant yields for new crops. The CREAMS and GLEAMS models were used to evaluate alternative planting dates, nitrogen (N) applications, soil types, and soil slopes (typical of the Georgia Coastal Plain) planted to rapeseed for the potential effects of these four variables on sediment, nutrient, and pesticide losses. Planting dates significantly affected runoff; total N leached; soluble and sediment-bound f. sulfoxide (in runoff); soluble, sediment-bound, and leached f. sulfone (metabolites of the nematicide fenamiphos); and soluble and leached metalaxil (fungicide). The first planting date, October 12, showed a significant reduction in losses compared to the third planting date, November 9. An evaluation of split N applications indicated a significant reduction in leached N as the number of splits increased for the same total N applied. Several of the sediment-bound pollutants in runoff increased significantly as slope increased. There is potential for reducing runoff losses by selecting soils with less slope or by using alternative management practices. The soil type influenced the pollutant losses in most cases. Greenville sandy clay loam had the greater losses of runoff-based pollutants, and Tifton loamy sand showed higher losses due to leaching for most parameters. Depending on the soil type and slope, careful selection of management practices can reduce the potential yield in rapeseed production.

OILSEED rape or rapeseed (*Brassica napus* L.) is a viable crop in many areas of the world. In fact, rapeseed oil commands about 10% of the world oilseed market and is expected to remain at this level in the future (*18*). Rapeseed is a versatile crop; varieties have been developed for consumptive (vegetable oil), industrial (lubricant), and fuel applications (*17*). Most current rapeseed varieties are adapted to the cooler climatic conditions of Canada and Northern Europe. New varieties are being developed with vernalization (chilling time) requirements that are more reasonable for the southeastern United States.

The potential for rapeseed production in the Southeast is high because of the long growing season and favorable climatic conditions. Rapeseed grown in the Southeast usually is planted in the fall and harvested in May or early June; thus, it has strong double-cropping potential (*25*).

Rapeseed also may provide sufficient canopy to be an alternative winter cover crop for reducing soil erosion (*6, 8, 17*). Unfortunately, there is little data available to evaluate accurately the erosion reduction potential of rapeseed. In Canada, the U.S. Northwest, and many areas of Europe, rainfall events are not as severe as the high-intensity, frontal and convective storms typical of the U.S. Southeast. In addition, the deep, volcanic ash-based soils of the Northwest are not susceptible to soil erosion under long-term, low-intensity rainfall events.

Some background

Recent legislation (1985 Food Security Act's Conservation Title) is a needed step toward soil erosion reduction (*16*). Several state programs list soil loss restrictive cropping rotations and tillage alternatives that are acceptable under the conservation provisions (*7*). Other programs identify generic crops based on residue production rather than specific crop rotations (*16*). The potential exists for a wide variety of planning programs that will provide needed soil loss reductions. Many of these plans, however, may not take into account potential new cropping systems and the absolutes associated with soil loss thresholds, and the ability to estimate or measure the soil loss is questionable (*5*).

Eroded sediment is not the only pollutant to be addressed. Nutrients and pesticides in surface waters and groundwater have become driving forces for new research and regulatory programs. Unfortunately, the cost and time required to perform long-term field studies to evaluate the pollution reduction potential of many possible cropping systems is unreasonable.

There are models available that can be used to identify potential alternatives in cropping management prior to extensive field study. SSAM (*1*), HSP (*9*), NPS (*4*), ARM (*3*), the Wisconsin model (*19*), CREAMS (*11*), and GLEAMS (*15*) all apparently have characteristics for evaluating agricultural management effects on surface and subsurface flow, chemical movement, and sediment yield (*20*). These models have been used in the Southeast. Our selection of a model was based on the widespread acceptability, use, and the degree of verification in the Georgia Coastal Plain. Based on this criteria, CREAMS and GLEAMS were selected. GLEAMS (*15*) is a new model developed from CREAMS (*11*). Both models provide estimates of sediment and pesticide yield for field-sized areas under different management scenarios. GLEAMS also predicts groundwater loadings—vertical flux past the root zone—for pesticides (*14*).

To evaluate the pollution potential associated with a new crop, such as rapeseed, one must assess the possible crop management alternatives. Rapeseed can be planted in the Southeast during a longer period than in the cooler climate of the Northwest. Planting date studies indicate that seed yield and biomass production remain relatively constant over a month-long planting interval (*24*). How these different planting dates may affect the potential sediment, nutrient, and pesticide losses has not been addressed.

Climatic variation is a primary factor that may affect pollutant loss estimates through different planting dates. Leonard and Knisel (*14*) simulated the effects of different planting dates on pesticide leaching losses for a corn crop on two representative soil types of the Georgia Coastal Plain for 50 years of historical rainfall. They evaluated a cross-section of different pesticide types with combinations of application methods, surface and injected; half-lives, 3 and 30 days; and partition coefficients, K_{OC}. They found that the half-life of a pesticide had a much larger effect on the loss of pesticides than the planting date. The longer half-life pesticides increased the total leaching losses by as much as an order of magnitude over the shorter half-life pesticides. There was a consistent effect due to planting date; the earlier

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date, March 15, had lower leaching losses than the later planting date, April 1, for the three-day half-life pesticides. The opposite was true for the 30-day half-life pesticides. The historical climatic period from late March to early April has a high percentage of percolation-producing storm events. The researchers concluded that the leached pesticide losses could be reduced on the average by timing the planting based on the pesticide type to be used. This study was performed on a warm-season crop, and the potential effects of planting dates on pesticide and other pollutant losses in the fall season were not addressed.

Knisel and associates illustrated the potential effects of split nutrient applications on nutrient losses using simulation results from the CREAMS model (*12*). In one example, a single fertilizer application of 140 kg/ha (125 pounds/acre) of nitrogen (N) was applied to corn at planting and compared to a split application of 28 kg/ha (25 pounds/acre) N at planting and 112 kg/ha (100 pounds/acre) N 30 days after corn emergence. The N leaching losses for the single N application were nearly double the split-application losses. There were no significant differences in N losses in runoff due to split applications. The combination of leaching and increased denitrification depleted the N supply and provided less N for plant uptake on the single N application. Increasing nutrient application splits, for the same total nutrient supply, should continue to reduce N losses. However, these results, measured or predicted, currently are not available in the literature.

These studies illustrate the potential application of models for predicting some pollution components, but the total pollutant effect of a particular crop has not been evaluated statistically. By simulating alternative management practices on a particular crop, we may be able to provide an optimal range of best management practices to minimize the potential pollution associated with that crop's production.

The objectives of our research were to anticipate rapeseed as a new crop in the Georgia Coastal Plain and evaluate, first, planting date effects on potential soil, nutrient, and pesticide losses in runoff; sediment-bound nutrient and pesticide losses; and nutrient and pesticide losses due to leaching and, second, the potential benefits of split N applications on runoff, sediment-bound, and leached N losses for two soils characteristic of the Georgia Coastal Plain. In addition, we evaluated the potential effects throughout the range of slopes associated with the soil types for the above conditions.

Study methods

Model inputs. Simulation of nutrient and pesticide leaching and surface runoff losses necessitated use of both the CREAMS (*11*) and GLEAMS (*15*) models because GLEAMS does not have a nutrient component. As a result, we used CREAMS to estimate the nutrient loss components and GLEAMS for the pesticide and sediment yield components.

The soil types chosen for the analysis were a Tifton loamy sand (typically-eroded, fine-loamy, siliceous, thermic, Plinthic Paleudult) and a Greenville sandy clay loam (clayey, kaolinitic, thermic, Rhodic Paleudult). These soil types are representative of the Georgia Coastal Plain, and both have suitable characteristics for rapeseed production. Current research indicates that high-sand, low clay-content soils (high leaching potential) may not be adaptable for rapeseed because of the major N and micronutrient requirements of the crop (*2*). Also, the poor seed/soil contact of sandy soils reduces the emergence of rapeseed.

The Tifton loamy sand typically has surface slopes between 2% and 5% were used. For this analysis, slopes of 2, 3.5 and 5% were used. The Greenville sandy clay loam has surface slopes of 4 to 12%; slopes of 4, 8, and 12% were used. For all simulations, the slope shape (overland) was assumed to be uniform, with a constant slope length of 200 m (656 feet).

Table 1 illustrates several of the input parameters for the two soil types used in the analysis. Both soils fall into the B runoff classification. A curve number of 75.0 was used on both soils by assuming rapeseed as a small grain, planted in straight rows, and with a good hydrologic condition (*23*). Further description of these soils can be obtained from soil surveys (*26, 27*) and other publications (*13, 14*).

One of the model inputs is the leaf area index. Leaf area index in this study was defined as the area of the plant leaves divided by the soil surface area. Because leaf area index is an input for evapotranspiration estimation and, thus, soil water content, representative leaf area index values are essential.

Limited data are available on the leaf area index of rapeseed. Wright and associates (*29*) evaluated the leaf area index of several Australian rapeseed varieties in northern Victoria, but the conversion of these values to the climatic and soil conditions of the Georgia Coastal Plain was not reasonable. In addition, the leaf area index values in that study were obtained on only three dates during the growing season.

Leaf area index values were based on rapeseed canopy cover data, which was converted to leaf area index. Thomas and daSilva (*24*) evaluated three rapeseed varieties (Westar, Cascade, and Dwarf essex) for three planting dates on a Tifton loamy sand in 1984 and 1985. Canopy cover estimates were obtained with overhead photographs of the rapeseed throughout the season. These slides were processed using a projection/gridding technique to provide an estimate of plant canopy cover (*25*). In the 1985 season, Thomas and daSilva (*24*) measured the leaf area index in combination with canopy cover estimates. Their limited leaf area index measurements were not sufficient to provide the data required for our study, but there was sufficient data to estimate the relationship between leaf area index and canopy cover. A regression analysis between leaf area index and canopy cover for the first planting date, using average values from both Westar and Cascade varieties, gave an r^2 of 0.95. As a result, we assumed the canopy cover values were representative of the leaf area index measurements of the rapeseed growth. Thomas and daSilva (*24*) noted that the effects on canopy cover of the three planting dates, October 12 and 25 and November 9, were negligible after January 31, so a single leaf area index curve was used for all three planting dates after January 31. Figure 1 illustrates the leaf area index (converted canopy cover) values used for the three planting dates in our analysis. Both CREAMS and GLEAMS estimate that leaf area indexes greater than 3.0 will result in maximum potential transpiration, so we selected the value of 3.0 to represent 100% canopy cover.

Table 1. Soil characteristics used in the simulations.

Soil Characteristic		*Tifton Loamy Sand*		*Greenville Sandy Clay Loam*	
Effective saturated conductivity	(mm/hr)	8.4		3.3	
Soil evaporation parameter		3.75		4.00	
Clay fraction*		0.08		0.25	
Silt fraction		0.12		0.20	
Sand fraction		0.80		0.55	
Soil horizons		1	2	1	2
Soil horizon depths from surface	(mm)	254.0	381.0	152.4	381.0
Soil porosity by horizon	(mm/mm)	0.40	0.40	0.40	0.40
Assumed field capacity	(mm/mm)	0.25	0.25	0.30	0.35
Assumed wilting point	(mm/mm)	0.05	0.05	0.18	0.22
Organic matter content	(% of soil mass)	0.70	0.70	0.88	0.55

*In the surface soil layer exposed to erosion.

Several erosion-based soil parameters were assumed to be the same for both soil types. These parameters included a kinematic viscosity of 1.55E-06 m²/sec, a soil weight density of 13.3 KN/m³, and a Yalin constant of 0.7. Other erosion-based parameters were assumed as the default in the models. We obtained the soil loss ratios for rapeseed from Wischmeier and Smith (*28*) through Table II-20 in Knisel (*11*). Line 152 of the table was used for the values, which represents grain after summer fallow with minimum row-crop residues prior to planting rapeseed. Manning's n values were estimated using Table II-26 from Knisel (*11*). Conventional tillage was assumed in all cases.

We set the effective rooting depth for rapeseed at 381 mm (15 inches) and the watershed area for simulation at 4.0 ha (10 acres).

We based the nutrient application sequences on actual N and phosphorus (P) applied to rapeseed in a production practice study during the 1987-1988 season (*2*). These included 157 kg/ha (140 pounds/acre) N in five splits (Table 2) and 50 kg/ha (45 pounds/acre) P applied on the planting date in all test combinations. A planting date (Julian) of 294 was used for all tests with the N split evaluation.

The pesticide applications for the planting date study were actual pesticide amounts and dates from the rapeseed production practice study (*2*). Rapeseed production is highly affected by soil and seed-borne pathogens, such as root knot nematodes, stem rot, root rot, and other pests (aphids and weeds). Table 3 shows the pesticide characteristics, dates of application, and method of application.

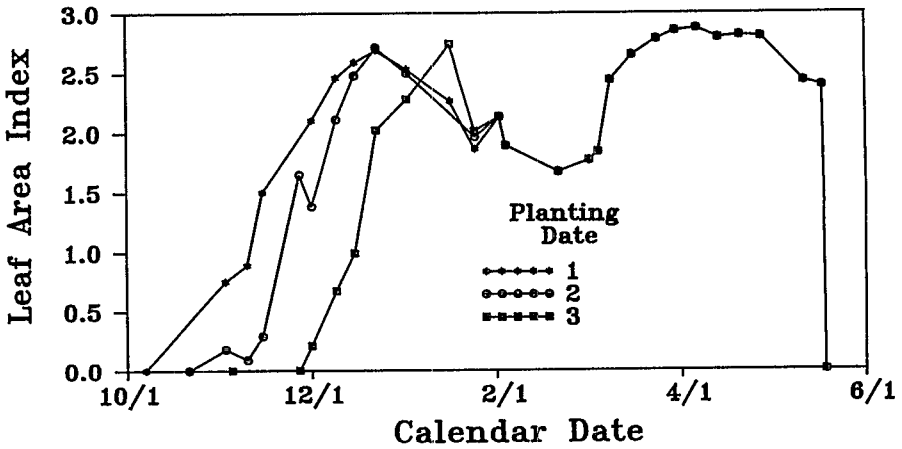

Figure 1. Leaf area index values for the three planting dates, October 12 (1), October 25 (2), and November 9 (3), used in the simulations.

The pesticide half-life and K_{OC} were not determined for the specific soils in this study, but were obtained from the default parameters in the GLEAMS software. These parameters often vary by factors of two to three between specific sites and methods of determination (*21*). Therefore, the results of this simulation are best interpreted as representative of a range of pesticide classes and application methods and not a prediction of absolute losses.

All of the simulation parameters related to the planting date—pre-emergence nutrient and pesticide applications, soil loss ratios, and Manning's n—were adjusted to conform with each planting date in the different input data sets.

The rainfall data used in the simulations was a 50-year record (1935-1985) from Tifton, Georgia. Average annual rainfall was 1,195 mm (47 inches) (*13*). Figure 2 illustrates the minimum, average, and maximum monthly rainfall for the entire 50-year record. The mean monthly air temperatures used in the simulations came from the Tift County soil survey (*27*). Temperatures ranged from 9.3°C (48°F) in January to 26.9°C (80°F) in July and August. The mean monthly solar radiation values (*10*) ranged from 9.3 MJ/cm²/day in December to 23.9 MJ/cm²/day in June. We used the same solar radiation and temperature data for each year of simulation.

Statistical analyses. The statistical analyses for the planting date and nutrient application studies need to be qualified due to the type of data generated. Each annual value from the simulation is the sum over the period between Julian dates 274 (October 1) and 153 (May 31). This means that only 8 months of the year are analyzed—those months associated with rapeseed production. The period between June 1 and September 30 was assumed to be in fallow. The relative effects of soil type, slope, planting date, and chemical application were the main concern and not the total annual pollutant values.

Another characteristic of the statistical analysis that is important is the sensitivity of the tests. With 50 years of data (50 sample values), the tests are highly sensitive to small variations between treatments. Therefore, a slight change in output values may produce a statistically significant effect.

Table 2. Amount of N applied for each treatment on the indicated Julian dates.

Treatment	Nitrogen Applied by Julian Date					
	PD*	343	20	63	83	Total
	kg/ha					
Planting date test	28	22	40	33	33	156
Nitrogen split test						
2 applications	78			78		156
3 applications	52		52	52		156
4 applications	39	39	39	39		156
5 applications	28	22	40	33	33	156

*PD corresponds to the planting date, which was Julian date 294 for the N split test and days 280, 294, and 308 for the planting date test.

Table 3. Pesticides applied for rapeseed production.

Pesticide	Description	Solubility (ppm)	Half-Life* (days)	Application			K_{OC}*†
				Date (Julian)	Rate (kg/ha)	Incorporation Depth (cm)	
Chlorothalonil	Fungicide	0.6	18.0	112	0.58	1.0‡	4,000
Fenamiphos	Nematicide	400.0	4.0	PPD§	6.73	5.0	400
F. sulfoxide	N. (metab.)	400.0	42.0	PPD	—	5.0	300
F. sulfone	N. (metab.)	400.0	18.0	PPD	—	5.0	200
Metalaxil	Fungicide	7,100.0	50.0	PPD	0.28	5.0	60
Acephate	Insecticide	650,000	2.0	318, 345	0.75	1.0	300
Trifluralin	Herbicide	1.0	60.0	PPD	1.68	5.0	1,200

*Half-life is in soil.
†K_{OC} is the partition coefficient; ratio of concentration of pesticide on organic carbon to concentration of pesticide in water.
‡The depth of incorporation of 1.0 cm is used for surface application.
§PPD corresponds to the day preceding the applicable planting date or pre-emergence application.

The potential effects of planting date, soil type, and slope on nutrient and pesticide loss, runoff, and erosion were evaluated with an analysis of variance using the general linear models procedure (22). The above analyses also were performed for each of the two soil types. The potential effects of nutrient application alternatives, soil type, and slope on N loss were evaluated with the same tests as with the planting dates. Duncan's multiple range test was used to indicate the relative significant differences between soil types, slopes, planting dates, and nutrient applications.

In all cases of the analysis of variance, highly significant and significant differences are indicated by probabilities exceeding 0.01 and 0.05, respectively. Duncan's multiple range test is based on probabilities exceeding 0.05.

Results and discussion

Planting date study. Two parameters of primary concern are the various treatment effects on runoff and sediment yield. Planting date had a significant effect on runoff. Because the Soil Conservation Service curve number approach is used to calculate runoff and runoff is based on soil water conditions at the time of the storm, the relative effects of the planting dates (differences in plant growth) and soil water-holding capacity were exhibited in the runoff. Duncan's multiple range test indicated that the runoff associated with planting date 3 was significantly higher than the runoff for planting date 1. Because the soil remained relatively uncovered, except for weeds, for a longer period under planting date 3, the potential for increased runoff is reasonable.

The planting date effect was present on the Tifton loamy sand (when analyzed separately) but was not present for the Greenville sandy clay loam. The mean statistics showed a 25% increase in total runoff, during the 8-month period of interest, from planting date 1 to 3 for the Tifton soil, while the Greenville soil had an 11% increase. Apparently, the Greenville sandy clay loam has sufficiently high slopes to negate the effect due to surface cover reductions, that is, different planting dates. As surface slope decreased, the influence of surface cover became more pronounced.

Soil type had a highly significant effect on runoff. Total runoff during the 8-month period on the Greenville soil was 18% higher than the total runoff from the Tifton soil. This was predominantly a result of the different water-holding capacities of the soils (Table 1).

The tests did not indicate a significant effect on sediment yield due to planting dates, although there was a slight increase in sediment yield as the planting date was delayed. Presumably, the effects due to soil type and slope outweighted the potential effects due to different planting dates. Soil type had a highly significant effect on sediment yield. This was obviously a characteristic of the different slopes between the soil types. A highly significant interaction existed between soil type and slope. Figure 3 illustrates the change in sediment yield due to the simulated soil and slope conditions. There were significant increases in sediment yield for each increase in slope (Duncan's multiple range test). The average sediment yield was 190% higher on the Greenville soil than on the Tifton soil. Sediment yield increased nonlinearly as the slope increased (Figure 3). The slope effect, of course, was based on a sloped plane for all simulations. The slope effect may have been different with a nonuniform slope and variations in the length factor. Also, the slopes were not comparable between soil types due to the different slope percentages used.

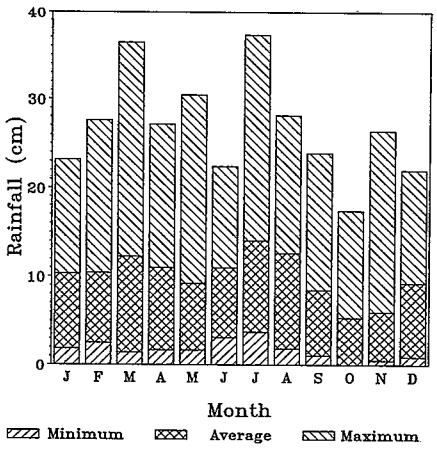

Figure 2. Average monthly rainfall characteristics (minimum, average, and maximum) for the period 1935 to 1985 at Tifton, Georgia.

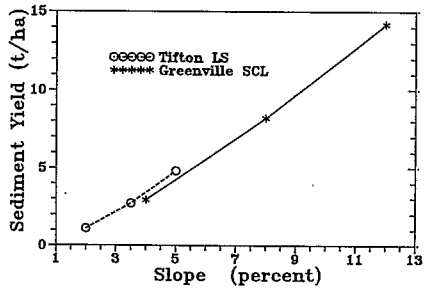

Figure 3. Soil type and slope effects on sediment yield.

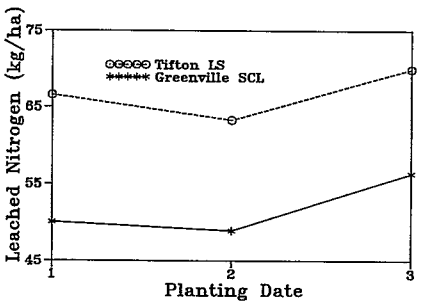

Figure 4. Soil type and planting date effects on total leached N.

One of the primary areas of concern in our study was the potential for reducing erosion with rapeseed. Average soil loss per season exceeded the "acceptable limit" of 2.2 t/ha (1 ton/acre) (Figure 3). Additional management practices probably would be necessary for all slope conditions on the Greenville sandy clay loam and probably for slopes greater than 2% on the Tifton loam sand. The combination of contour farming and terraces may provide a 30 to 70% reduction in soil loss (28). However, even with the maximum potential benefit of these two practices, it is questionable whether rapeseed can help to maintain an acceptable level of soil loss for the highly sloped Greenville soil.

The simulated results of N and P losses showed that planting date had a highly significant effect on leached N. No statistically significant planting date effects occurred on total losses of either soluble or sediment-bound N or P in runoff. Denitrification also was not significantly affected by planting dates. On the average, leached N losses accounted for about 88% of the total N losses on the Tifton soil and about 72% of the losses on the Greenville soil. Therefore, efforts to minimize N leaching may result in greater total pollution reduction than efforts aimed at runoff losses. Figure 4 shows the effects of planting date and soil type (also a highly significant effect) on total leached N. The average leached N loss from the Greenville soil was 29% less than the loss from the Tifton soil. Leached N decreased for planting date 2, compared with planting dates 1 and 3. But Duncan's multiple range test showed that only planting date 3 had significantly higher leached N losses than planting dates 1 and 2. When the Tifton loamy sand was analyzed separately, the 10% reduction in leached N losses between planting dates 3 and 2 were the significant effects (Duncan's multiple range test). On the Greenville soil, the 15% reduction in leached N losses between planting dates 3 and 1 and the 13% reduction between planting dates 3 and 2 were significant.

From these results, an apparent window exists in the rainfall history that shows less severe leaching events near October 25 than November 9 or October 11. From the summary rainfall data (Figure 2). Less rainfall occurs in October compared to other months. Whether these event patterns are re-

peatable in the future remains to be seen. Thus, there may be potential for reducing N leaching losses by planting rapeseed in late October rather than dates much earlier or later. Of course, the variabilities associated with parameter estimation and model relationships would indicate that the small change in leached N losses between the first and second planting dates, especially for the Greenville soil, is probably not sufficient to warrant a change in planting dates due to N leaching alone. A combination of the effects from the other chemicals may provide a stronger conclusion.

One characteristic of the simulation procedures that may have influenced this result is the constant tillage, planting, and nutrient and pesticide application dates each year. In some years, a rainfall event may have occurred in conjunction with one of these activities and caused a much greater effect than under actual situations where a farmer may anticipate rainfall events and adjust management schedules accordingly. An additional modelling routine to adjust planting and application dates that are coincident with rainfall events may be necessary.

Soil type had highly significant effects on soluble N and P losses and sediment-bound N and P losses (in runoff). In all cases, soil loss on the Greenville silty clay loam was greater than on the Tifton loamy sand. On the average, about 14% and 3% of the total N losses were attributed to sediment-bound N for the Greenville and the Tifton soils, respectively. However, there was a highly significant interaction between soil type and slope for the sediment-bound N and P losses. With steep slopes, sediment-bound N contributed 23% and 4% of the total N lost on the Greenville and Tifton soils, respectively. A 350% increase in sediment-bound N losses occurred from slope 1 to 3 on both soil types. This increase was not as severe as the sediment yield increase due to slope (over 430% from Figure 3), but the need to reduce the potential erosion and sediment-bound nutrient losses with appropriate management practices is apparent. The relative losses for soluble and sediment-bound P were in relation to the N losses, but the magnitude of the P losses was less than 40% of the N losses.

Denitrification contributed 12% and 8% of the total N losses for the Greenville and Tifton soils, respectively. Soil type had highly significant effects on denitrification, although the actual simulated differences were minimal. Denitrification in the Greenville soil was about 28% higher than for the Tifton soil.

The pesticides of major importance for the planting date study were those associated with pre-emergence application. Fenamiphos, metalaxil, and trifluralin were the pre-emergence pesticides used on the rapeseed (Table 3). The simulated pesticide losses in runoff—soluble and sediment-bound—and leached through the soil profile indicated that leaching would be the major contributor to pesticide loss for most of these pesticides, except trifluralin, on these soils (Figure 5). The total relative pesticide losses (Figure 5) can be used with the total application amounts (Table 3) to estimate the total loss as a percentage of application. When analyzing the leaching losses, planting date had a highly significant effect on leaching only for metalaxil (fungicide). Leaching below the root zone accounted for 99% of the total metalaxil lost. Leaching increased as the planting date was delayed, with simulated increases of 68% and 46% from planting date 1 to 3 for the Tifton and the Greenville soils, respectively (Figure 6). Metalaxil is highly water-soluble (7,100 ppm) and may have a relatively long half-life (50 days), which are ideal properties for leaching. The 50-day period following the earlier planting date is drier than the same period following the later planting dates; thus, there is increased leaching potential for the later dates.

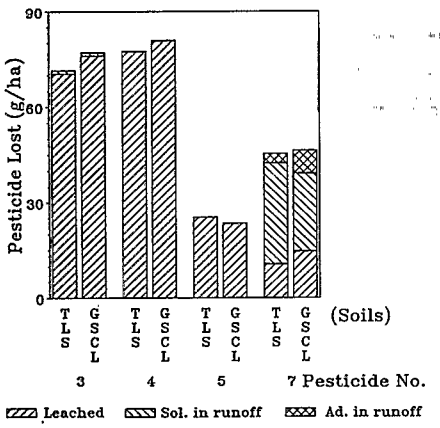

Figure 5. Average contributions from soluble and sediment-bound runoff and leaching for the pesticides f. sulfoxide (3), f. sulfone (4), metalaxil (5) and trifluralin (7) lost from the Tifton loamy sand (TLS) and the Greenville sandy clay loam (GSCL).

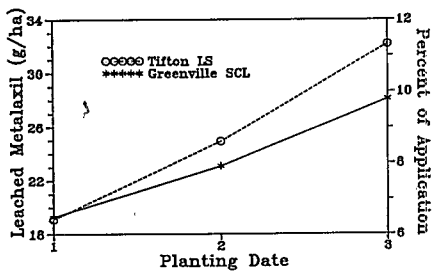

Figure 6. Soil type and planting date effects on leaching losses of the fungicide metalaxil.

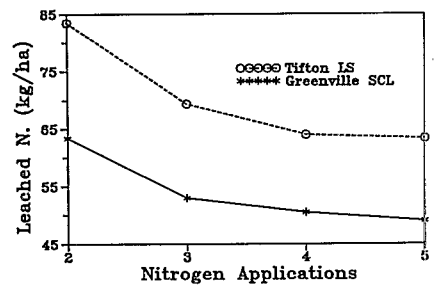

Figure 7. Soil type and N application technique effects on N leaching losses.

The only other statistically (highly) significant effect on leaching losses was a soil type effect on trifluralin (herbicide). The leaching losses were about 37% higher for the Greenville soil than for the Tifton soil (Figure 5). This may be associated with the differences in organic matter in the lower soil horizons and the partition coefficient of trifluralin because trifluralin is strongly adsorbed. The leaching losses of trifluralin were, however, relatively small in both soils.

The planting date effects on runoff losses (soluble) were highly significant for f. sulfone and metalaxil and were significant for f. sulfoxide. However, these effects were tempered by the fact that less than 2% of the losses of these three pesticides were in the soluble form in runoff. These losses are well below any level of biological consequence. In all cases, the first planting date showed significantly less pesticide loss than the third planting date. The soluble trifluralin loss was the major contributor to total trifluralin losses. The ratio of soluble to total trifluralin losses was 70% and 53% for the Tifton and Greenville soils, respectively (highly significant soil type effect). The persistence and characteristics of trifluralin may be a potential problem for this type of application on rapeseed.

The planting date effect on sediment-bound pesticide loss in runoff was significant for f. sulfone, but the total loss was less than 1%. As with soluble runoff losses, the first planting date showed less total loss compared to the later planting dates. The soil/slope interaction had highly significant effects on sediment-bound losses of f. sulfoxide, f. sulfone, and trifluralin. Losses of all three pesticides were greater for the Greenville soil and for increasing slope.

Sediment-bound fenamiphos also was affected by soil type and slope differences in a manner similar to the other pesticides. The only difference was a reduced effect due to slope. From the first to the third slope, sediment-bound fenamiphos losses increased significantly.

Nitrogen application study. The evaluation of different split applications of N showed that leaching was the major source

of N loss in leached water and runoff. As indicated in the planting date study, leached N losses contributed about 88% and 72% of the total losses from the Tifton loamy sand and the Greenville sandy clay loam, respectively. Application had a highly significant effect on leached N losses, with a decrease in N loss as the number of splits increased. Duncan's multiple range test showed significant differences between the two, three, and five split applications (Table 2). Leached N losses decreased about 24% from the two to five split applications on each soil type. When each soil type was analyzed separately, the three, four, and five split applications did not show a significant difference. Figure 7 illustrates the effects of soil type on leached N losses due to nutrient application.

The effects on soluble and sediment-bound N and leached N due to soil type and slope were similar to those exhibited in the planting date study and are not discussed here. Increasing the number of split applications of N appears to be effective for reducing N losses, but the statistical analysis and simulated results indicate a reduction in effectiveness for three or more applications. Additional simulation and field data will be required to evaluate the N losses as the splits approach the level of spoon-fed or prescription application.

Nutrient applications had highly significant effects on denitrified N losses similarly to the leaching results. The two split application had significantly higher denitrification losses as compared to the other splits. In addition, the four split application showed significantly lower losses compared to the two and three split applications. When the soils were analyzed separately, only the two split application had significantly higher losses of N by denitrification compared to the other splits. Later in the growing season, conditions probably were more favorable for denitrification. The most effective application split for reductions in denitrification losses appears to be four splits for these particular conditions. A 29% decrease in denitrification losses was achieved by increasing the splits from two to four.

Conclusions

The possibility for reducing potential pollution from rapeseed production in the Georgia Coastal Plain through selected management practices has been demonstrated with simulation. Of the three planting dates chosen—October 12 and 25 and November 9, the first and second dates exhibited the best potential for pollution reduction. In some cases, such as soluble runoff losses and leaching of the fungicide metalaxil, significantly less pesticide loss occurred for the first planting date compared to the other planting dates. None of the simulated pollutants showed a significant reduction in losses with the third planting date.

Previous studies have shown that the window for rapeseed planting is fairly large, with little effect on yield between the earliest and latest planting dates. Additional research is underway to evaluate the limits of the planting window for rapeseed in the Georgia Coastal Plain.

Leaching of nutrients and pesticides should be a major concern for production. The use of split N applications probably will help to reduce leaching and denitrification to a certain degree, but a reduction in the total nutrient application or evaluation of spoon-feeding may be necessary. Additional research is needed on the balance between productivity level and the economics of nutrients applied and lost. Estimated pesticide leaching losses were substantial, as high as 9% of the application for metalaxil. Alternative pesticides with shorter half-lives and improved characteristics may be necessary to reduce these potential losses.

Soil type and slope affected pollutant yield in many cases. Improved conservation practices, such as reduced tillage, no-till, terraces, etc., are required to reduce potential sediment and sediment-bound nutrient losses if rapeseed is to be grown on soils similar to the Greenville sandy clay loam. The high-slope sandy clay loams may not be suited to rapeseed production, but field evaluation of this particular scenario may be necessary before these type soils are completely ruled out.

These results are based on simulations and are not meant to provide actual pollutant yield values for the different scenarios tested. In fact, measurements of pollutant yields on particular field studies may be orders of magnitude from the simulated values. However, the relative nature of the analysis should provide a reasonable estimate of the changes in pollutant yields that can be expected for rapeseed production under the tested conditions, on average.

For interpretation and use of these results, it is appropriate to provide an example of a potential application. Consider a condition where rapeseed is to be planted in the Coastal Plain and the land region is in a groundwater recharge area where leaching would be a major concern. Consider also, that N is the major potential problem in the groundwater resource. Based on the rapeseed production practices in this simulation study, one could expect a 30% decrease in leached N on the average by planting rapeseed around October 25, versus November 9, on a Greenville sandy clay loam, versus a Tifton loamy sand. In addition, by applying N in five split applications, versus two, one may expect an additional 23% decrease in leached N. This is only one potential scenario and others could be evaluated using the same procedures.

REFERENCES CITED

1. Betson, R. P. 1972. *Storm hydrographs using a double-triangle model.* Res. Paper No. 8. Tenn. Valley Authority, Knoxville.
2. Breve, M. A., D. L. Thomas, and P. A. Raymer. 1988. *Rapeseed production practice evaluation.* Agr. Eng. Dept., Univ. Ga., Tifton.
3. Crawford, N. H., and A. S. Donigian, Jr. 1973. *Pesticide transport and runoff model for agricultural lands.* EPA-660/2-74-013. Off. Res. and Develop., U.S. Environ. Protection Agency, Washington, D.C. 211 pp.
4. Donigian, Jr., A. S., and N. H. Crawford. 1976. *Agricultural runoff management (ARM) model.* Hydrocomp Inc., Palo Alto, Calif.
5. Gray, M. 1988. *What constitutes compliance?* J. Soil and Water Cons. 43(1): 39.
6. Hairston, J. E., J. O. Sanford, V. H. Watson. 1984. *Rape as a winter oilseed crop in Mississippi.* Miss. Agr. and Forestry Exp. Sta. Res. Highlights (June). 7-8.
7. Holtsclaw, L. 1988. *Conservation planning by hydrologic units.* J. Soil and Water Cons. 43(1): 47-48.
8. Hoveland, C. S., J. W. Odom, R. L. Haaland, and M. W. Alison, Jr. 1981. *Rapeseed in Alabama.* Bull. No. 532. Ala. Agr. Exp. Sta., Auburn University.
9. Hydrocomp. 1976. *Hydrocomp simulation programming operations manual.* Hydrocomp Inc., Palo Alto, Calif.
10. deJong, B. 1973. *Net radiation received by a horizontal surface at the Earth.* Deft Univ. Press. Rotterdam, The Netherlands.
11. Knisel, W. G., ed. 1980. *CREAMS: A field-scale model for chemicals, runoff, and erosion from agricultural management systems.* Cons. Res. Rpt. No. 26. U.S. Dept. Agr., Washington, D.C. pp. 643.
12. Knisel, W. G., G. R. Foster, and R. A. Leonard. 1983. *CREAMS: A system for evaluating management practices.* In F. W. Schaller and G. W. Bailey [eds.] *Agricultural Management and Water Quality.* Iowa Univ. Press, Ames. pp. 178-199.
13. Knisel, W. G., and R. A. Leonard. 1986. *Impact of irrigation on groundwater quality in humid areas.* In M. Karamouz et al. [eds] *Water Forum '86: World Water Issues in Evolution.* Am. Soc. Civil Eng., New York, N.Y. pp. 1508-1515.
14. Leonard, R. A., and W. G. Knisel. 1988. *Evaluating groundwater contamination potential from herbicide use.* Weed Tech. 2: 207-216.
15. Leonard, R. A., W. G. Knisel, and D. A. Still. 1987. *GLEAMS: Groundwater loading effects of agricultural management systems.* Trans., ASAE 30(5): 1403-1418.
16. Lewis, S. L. 1988. *The changing nature of conservation planning.* J. Soil and Water Cons. 43(1): 40-43.
17. Lyons, S. 1987. *Food, fuel and hope.* Idaho, The University 4(3): 11-14, 23-24.
18. Mielke, S. 1987. *Outlook to 1995: World production, consumption.* Oilseeds Outlook, J. Am. Oil Chemists' Soc. 64(3): 294-298.
19. Patterson, M. R. et al. 1974. *A user's manual for the FORTRAN IV version of the Wisconsin hydrologic transport model.* ORNL/NSF/EATC -7,EDFB/IBP/74-9. Oak Ridge Nat. Lab., Oak Ridge, Tenn.
20. Renard, K. G., W. J. Rawls, and M. M. Fogel. 1982. *Currently available models.* In C. T. Haan, H. P. Johnson and D. L. Brakensiek [eds.] *Hydrologic Modeling of Small Watersheds.* Mono. No. 5. Am. Soc. Agr. Eng., St. Joseph, Mich.
21. Rao, P. S. C., and J. Davidson, [eds.] 1982. *Retention and transformation of selected pesticides and phosphorus in soil-water systems: A critical review.* EPA-600/3-82-060. U.S. Environ. Protection Agency, Washington, D.C.
22. SAS Institute, Inc. 1982. *Statistical Analysis System.* Cary, N. Car.

23. Schwab, G. O., R. K. Frevert, T. W. Edminster, and K. K. Barnes. 1981. *Soil and water conservation.* John Wiley and Sons, New York, N.Y. p. 74.
24. Thomas, D. L., and F.J.K. daSilva. 1987. *Evaluation of rapeseed as a winter cover crop in south Georgia.* Agr. Eng. Dept., Univ. Ga. Tifton.
25. Thomas, D. L., F.J.K. daSilva, and W. A. Cromer. 1988. *Image processing technique for plant canopy cover evaluation.* Trans., ASAE 31(2): 428-434.
26. U.S. Department of Agriculture. 1983. *Soil survey of Dooly and Macon Counties, Georgia.* Soil Cons. Serv., Washington, D.C.
27. U.S. Department of Agriculture. 1983. *Soil survey of Tift County, Georgia.* Soil Cons. Serv., Washington, D.C.
28. Wischmeier, W. H., and D. D. Smith. 1978. *Predicting rainfall erosion losses.* Agr. Handbk. No. 537. U.S. Dept. Agr., Washington, D.C. pp. 58.
29. Wright, G. C., C. J. Smith, and M. R. Woodroofe. 1988. *The effect of irrigation and nitrogen fertilizer on rapeseed* (Brassica napus) *production in South-Eastern Australia. I. Growth and seed yield.* Irrig. Sci. 9: 1-13. □

The economic impact of conservation compliance on northern Missouri farms

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ABSTRACT: Individual farmers and other landowners are expected to base their decisions on whether to participate in conservation compliance primarily on economic criteria, with profitability being an important determinant. Crop budgets were developed to identify the crop rotation that will generate the most net revenue for each of several conservation practices that meet a soil erosion goal of T—the soil tolerance value. The budgets show an economic advantage for soybeans over corn, wheat, and forages, regardless of the price scenario, in northern Missouri. If compliance reduces soybean production, the impact will be lower economic returns to land and management and, subsequently, to the value of the land itself. Educational programs warning investors of this potential outcome would be appropriate. Alternatives, such as long-term easements, new crops, and new cultural practices, need to be developed to help farmers (landowners) shift out of agricultural enterprises that are neither consistently profitable nor resource-sustainable.

THE conservation provisions of the 1985 Food Security Act have been justified as programs that reduce soil erosion, restrain the production of surplus commodities, improve water quality, and benefit wildlife. However, individual farmers and other landowners are expected to base their decisions on whether to participate in the various programs primarily on economic criteria, with profitability being an important determinant. The attraction of the Conservation Reserve Program (CRP) is that rent is paid. For conservation compliance, to which this analysis is directed, the incentive is different. It is the potential loss of various U.S. Department of Agriculture (USDA) program benefits if the farmer or landowner fails to comply that is at stake.

The hypothesis tested here is that the fate of conservation compliance will be determined largely by local economic conditions. In this analysis, we assumed that profitability will be an important determinant to future land use and that the land use will be traditional farming. Although other types of land use, such as agroforestry and fee hunting, are potential future alternative uses, we assume farmers or landowners will continue to choose more traditional agricultural enterprises that appear to them to be more profitable and/or less risky.

We based our research on the supposition that crop budgets are the building blocks for determining the likely economic attractions of different combinations of rotations and mechanical practices that a farmer can use to qualify for USDA program benefits under conservation compliance. Hence, we took a micro-oriented approach to identify the crop rotation that will generate the most net revenue for each of several conservation practices designated to hold soil erosion under the soil loss tolerance (T) value and without soil conservation for soils aggregated by land capability classes. The T value is defined as "the maximum rate of soil erosion that will permit a high level of crop productivity to be sustained economically and indefinitely" (*3*).

Alternative conservation systems, which allow soil erosion to exceed T, have been approved by the Soil Conservation Service (SCS). These conservation system alternatives will be discussed later.

Assumptions

The implications of this study are strongly influenced by the study assumptions. The most important assumptions include:

- Conservation compliance will not go away.
- Compliance can be met by some combination of crop rotation and mechanical practice that reduces soil erosion to T.
- Most farmers will accept compliance requirements to continue so they can participate in various USDA programs.
- Homogeneity of yield and erosion potential represented by point estimates can be assumed for soils within land capability classes.

Study methods

We calculated returns to land and management for a matrix of four soil management practices. Three conservation practices used the most intensive (profitable) crop rotations allowable with a soil erosion goal of T. The conservation practices included contouring; contouring with conservation tillage, 30% residue after planting; and terraces with conservation tillage. The goal of the fourth practice was to achieve maximum profit without regard to erosion.

Table 1. Price scenarios used in analysis of economic impact of conservation compliance.*

Commodity	Low Price Scenario	Medium Price Scenario	High Price Scenario
Corn ($/bushel)	1.90	2.35	3.00
Soybean ($/bushel)	4.75	5.90	7.50
Wheat ($/bushel)	2.20	2.70	3.45
Alfalfa/ grass hay ($/ton)	60.00	65.00	70.00
Red clover Grass hay ($/ton)	50.00	55.00	60.00
Pasture ($/animal unit month)	6.00	7.00	8.00

*Given a 10-year planning horizon, no government price support programs were assumed. Hence, three levels of prices were used for the reader to select the most appropriate in his/her judgment.

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Three price scenarios (Table 1) were chosen not only to represent low, medium, and high commodity price expectations but to keep commodity prices in a realistic, historical relationship (ratio to corn as 1.00; wheat, 1.15; soybeans, 2.5). Obviously, other combinations of prices, conservation practices, and crop rotations could be used. However, we believe these choices were sufficiently reasonable so that the data generated from this analysis allows insights to be obtained into the likely impact of conservation compliance.

The common denominator for crop yield data and universal soil loss equation (USLE) factors is the soil mapping unit. This unit represents a portion of the landscape that has similar characteristics and qualities and whose limits are fixed by precise definitions (*4*). Soil surveys contain maps of landscapes portioned into soil mapping units. The surveys also include information on management practices and estimated yields related to the individual mapping units. For this study, we used the modern soil surveys for Clay and Ray Counties, located in west central Missouri, as the source for crop yield and soil erosion factor data. The soil mapping units in these surveys were considered representative of a variety of natural resource conditions in northern Missouri.

The crop yields, soil erosion factors, and map unit acres were recorded for land capability classes IIe, IIIe, IVe and VIe (Table 2). Forage yields were estimated by University of Missouri extension personnel. Corn, soybean, and wheat production is not recommended by SCS for land capability classes greater than IV; therefore, no yield data are reported. In practice, these crops are produced on some class VI and class VII soils; however, yield data were not available for development of budgets.

The SCS land capability classification system groups soils according to their potentials and limitations for sustained production of the common cultivated crops (*4*). This classification system is not the best for aggregating soils by yield potential. For example, note the yield similarities for soil mapping units in class II and class III (Table 2). However, there is a good relationship between slope class and capability class, in that, as the slope of the soil mapping units increases, the soils are placed in higher numbered capability classes. In general, class II soils are found on 2-5% (B) slopes, class III soils on 5-9% (C) slopes, and class IV soils on 9-14% (D) slopes.

We found that row-crop and wheat yields increased by about 10% over a 10-year period based on Missouri crop yield data (*1*). Therefore, we adjusted crop yields (Table 2) by 1% per year or a 10-year planning horizon in anticipation of continued improvement in varieties and crop production technologies. The soil mapping unit yields and soil erosion factors were condensed into acreage weighted values by land capability class.

Table 2. Yield and soil loss data from soil surveys for Clay and Ray Counties, Missouri.

Soil Mapping Unit	Adjusted Yield*			Soil Loss Factors: Erosion Tolerance (T)	Soil Erodibility (K)	Slope Length and Steepness† (LS)	Acres Clay and Ray Counties	
	Corn	Soybeans	Wheat	(t/acre)			Acres	Percent
	— bushels/acre —							
Land capability class IIe								
Sibley 1B	127	50	53	5	.28	.51	4,700	6.7
Sharpsburg 6B	112	47	50	5	.32	.83	35,100	50.2
Sampsel 13B	95	36	39	3	.37	.53	2,760	4.0
Lagonda 24B	99	37	42	3	.37	.53	7,950	11.4
Ladoga 26B	101	39	43	5	.32	.47	7,250	10.4
Grundy 56B	108	42	44	3	.37	.54	12,090	17.3
Weighted average‡	109	44	47	4.4	.33	.52	69,850	100.0
Land capability class IIIe								
Sibley 1C	119	43	44	5	.28	.81	4,575	2.1
Higginsville 2C	119	45	50	5	.37	1.30	3,440	1.6
Macksburg 5C	118	43	47	5	.32	1.10	21,650	9.8
Sharpsburg 6C2	99	44	46	5	.32	1.17	38,950	17.7
Sharpsburg 6D2	90	33	37	5	.32	2.30	9,100	4.1
Greentown 11C2	85	31	34	3	.37	1.17	11,800	5.4
Sampsel 13C	87	33	33	3	.37	.88	4,330	2.0
Lagonda 25C2	84	31	37	3	.37	.99	61,050	27.8
Ladoga 26C2	88	33	36	5	.32	.92	13,600	6.2
Ladoga 26D2	77	29	31	5	.32	1.90	7,550	3.4
Armster 41C2	64	28	31	5	.37	.93	28,450	12.9
Knox 54C2	98	36	37	5	.32	1.01	8,850	4.0
Grundy 57C2	88	33	37	3	.37	1.01	6,700	3.0
Weighted average‡	89	35	39	4.2	.35	1.11	220,045	100.0
Land capability class IVe								
Snead 9D	61	23	28	3	.37	2.10	10,650	17.6
Greentown 11Ce	—	—	29	2	.37	1.20	2,340	3.9
Ladoga 27D3	68	25	28	5	.32	1.95	4,650	7.7
Armster 41D2	55	24	28	5	.37	2.20	16,400	27.1
Amster 42C3	57	20	24	4	.37	.96	3,350	5.5
Knox 54E2	—	—	—	5	.32	3.75	8,200	13.6
Knox 55D3	72	26	29	6	.32	1.90	14,900	24.6
Weighted average‡	63	24	27	4.5	.35	2.19	60,490	100.0
Land capability class VIe								
Snead 9E	—	—	—	3	.37	4.20	1,223	5.6
Greentown 11D3	—	—	—	2	.37	2.30	8,090	37.3
Lagonda 25d2	—	—	—	3	.37	2.30	2,510	11.6
Amster 42E3	—	—	—	4	.37	2.00	3,610	16.7
Knox 54F	—	—	—	5	.32	7.00	6,250	28.8
Weighted average‡				3.4	.36	3.71	21,683	100.0

*Published soil survey yields were increased 10% to account for yield increases due to improved varieties and new technology.
†Estimates from SCS tables developed for completion of CRP worksheets.
‡Weighted by the mapping unit acres within each land capability class. Numbers in last two columns are totals.

As a step in the analysis, we constructed partial budgets to project future income and expenses (Tables 3-8). These budgets were modified after Blase (*2*). We used the *Missouri Farm Planning Handbook* (*6*) as the principal source for most crop production costs. Fertilizer requirements were based on a soil fertility maintenance program for predicted yield levels. Labor was assigned a wage rate of $5.00 per hour.

The budgets were adjusted to make inputs consistent for expected yields of soils aggregated by land capability class. For example, seed, fertilizer, machinery maintenance, and other variable costs fall as yields decrease. Likewise, variable costs are higher for alfalfa hay than for red clover/grass hay. The generated costs illustrate a point that many farmers overlook. Marginally productive soils require relatively high commodity prices to generate a profit.

The costs and/or potential returns directly attributable to conservation practices were not included in the analysis. The conservation costs are highly site-specific and, in the case of building and maintaining terraces, can exceed the costs associated with crop production.

After we developed the partial budgets, we summarized the profit or loss for each crop by land capability class for each of the three price scenarios (Table 9).

Finally, returns to land and management for the most profitable rotation permitted by a soil erosion goal of T and without soil conservation were calculated by land capability class, price scenario, and management practice (Table 10). We used the USLE to estimate soil erosion for various crops and conservation practices. This process required several iterations to arrive at the most profitable crop rotation by conservation system and land capability class. When the rotation returns were negative, we assumed that the land would revert to the least-cost use, low-input pasture.

As stated earlier, many combinations of the above variables could have been used in the analysis. Those chosen here are considered illustrative of the variety of conservation practice alternatives that can be used to meet the conservation compliance provision.

Analysis and discussion

Returns to land and management. Given the large number of budgets generated, our discussion focuses initially on the low price projection for the corn budget (Table 3). Budgets were calculated for land capability classes II, III, and IV. On a price assumption for corn of $1.90/bushel, we calculated gross income by multiplying price times yield. The total variable costs were subtracted from the gross income and reported as income over variable costs. In turn, we subtracted machinery depreciation and labor costs per hectare, leaving a balance that represents the return to land and management.

The price of corn necessary to break even over the 10-year planning horizon for the low price scenario [(variable costs + machinery + labor)/yield] is $1.89, $2.13 and $2.70/bushel, respectively, for class II, III and IV land, respectively. These break-even prices do not take into account that most rolling-landscape fields contain soils of varying yield potentials. Farmers generally manage for yield expectations based on the more productive soils within a field and, therefore, do not adjust inputs downward for less productive soils within a field.

Note that the low price scenario generates negative returns for all crops on all classes of land considered except corn on class II land and soybeans on classes II and III land (Table 3-4). This result is one reason why the soybean hectarage has been so large in

Table 3. Corn, soybean, and wheat budgets by land capability class, low price scenario, northern Missouri.

	Corn			*Soybeans*			*Wheat*		
	Land Capability Class			*Land Capability Class*			*Land Capability Class*		
Item	*IIe*	*IIIe*	*IVe*	*IIe*	*IIIe*	*IVe*	*IIe*	*IIIe*	*IVe*
Yield (bushel/acre)	109	89	63	44	35	24	47	39	27
Price ($/bushel)	1.90	1.90	1.90	4.75	4.75	4.75	2.20	2.20	2.20
					$/acre				
Gross income	207.00	169.10	119.70	209.00	166.25	114.00	103.40	85.80	59.40
Variable costs									
Seed	17.75	16.00	14.00	12.00	12.00	12.00	12.00	12.00	12.00
Fertilizer	43.99	36.66	28.36	18.07	13.41	12.01	23.28	21.03	15.86
Chemicals	19.00	19.00	19.00	21.00	21.00	21.00	—	—	—
Machine hire	5.00	5.00	5.00	—	—	—	4.00	4.00	4.00
Machine maintenance	32.00	30.00	27.25	30.50	32.00	28.00	21.50	20.00	18.00
Haul/dry	16.50	13.35	9.45	4.40	3.50	2.40	4.70	3.90	2.70
Miscellaneous	7.01	6.30	5.45	5.25	4.90	4.72	3.27	3.05	2.63
Interest	8.10	7.28	6.30	6.06	5.66	5.45	3.78	3.52	3.04
Total	149.35	133.59	114.81	97.28	92.47	85.58	72.53	67.50	58.23
Income over variable cost	63.75	35.51	5.11	111.72	73.78	28.42	30.87	18.30	1.17
Labor (hours)	3.4	3.1	3.0	3.2	3.1	3.0	1.6	1.5	1.4
Machinery depreciation plus labor	57.00	55.75	55.00	56.00	55.50	55.00	48.00	47.50	47.00
Return to land	0.75	−20.25	−50.11	55.72	18.28	−26.58	−17.13	−29.20	−45.83

Table 4. Legume and grass hay and pasture budgets by land capability class, low price scenario, northern Missouri.

	Legume and Grass Hay				*Pasture*				*All Soil Types, Minimum-Input Fescue*
	Land Capability Class				*Land Capability Class*				
Item	*IIe*	*IIIe*	*IVe*	*VIe*	*IIe*	*IIIe*	*IVe*	*VIe*	
Yield (bushel or AUM*/acre)	3.6	2.9	2.2	1.9	7.3	6.4	5.4	5.0	3.0
Price ($/ton or AUM)	60.00	60.00	50.00	50.00	6.00	6.00	6.00	6.00	6.00
					$/acre				
Gross income	216.80	174.60	110.80	95.00	43.80	38.40	32.40	30.00	18.00
Variable costs									
Establishment	29.00	27.00	11.00	11.00	5.00	5.00	5.00	4.00	4.00
Fertilizer, lime	34.75	29.76	19.92	17.69	38.83	34.70	29.82	26.68	6.00
Crop chemicals and supplies	10.00	10.00	7.00	7.00	2.00	2.00	2.00	2.00	1.00
Machine maintenance	47.00	42.00	32.00	31.25	2.00	2.00	2.00	2.00	2.00
Miscellaneous	3.00	3.00	3.00	3.00	—	—	—	—	—
Interest	6.81	6.15	4.01	3.85	2.63	2.40	2.14	1.91	.72
Total	130.56	117.91	76.93	73.79	50.46	46.10	40.96	36.59	13.72
Income over variable cost	85.44	56.09	33.07	21.21	−6.66	−7.70	−8.56	−6.59	4.28
Labor (hours)	10	9.0	6.0	6.0	1.5	1.5	1.5	1.5	1.0
Machinery depreciation plus labor	90.00	85.00	70.00	70.00	7.50‡	7.50‡	7.50‡	7.50‡	5.00‡
Return to land	−4.56	−28.91	−36.93	−48.79	−14.16	−15.20	−16.06	−14.09	−0.72

*Animal unit month.
†Legume is alfalfa for classes II and III and red clover for IV and V.
‡Labor only.

Table 5. Corn, soybean, and wheat budgets by land capability class, medium price scenario, northern Missouri.

Item	Corn			Soybeans			Wheat		
	Land Capability Class			Land Capability Class			Land Capability Class		
	IIe	IIIe	IVe	IIe	IIIe	IVe	IIe	IIIe	IVe
Yield (bushels/acre)	109	89	63	44	35	24	47	39	27
Price ($/bushel)	2.35	2.35	2.35	5.90	5.90	5.90	2.70	2.70	2.70
					$/acre				
Gross income	256.15	209.15	148.05	259.60	206.50	141.60	126.90	105.30	72.90
Variable costs									
Seed	17.75	16.00	14.00	12.00	12.00	12.00	12.00	12.00	12.00
Fertilizer	43.99	36.66	28.36	18.07	13.41	12.01	23.28	21.03	15.86
Chemicals	19.00	19.00	19.00	21.00	21.00	21.00	—	—	—
Machine hire	5.00	5.00	5.00	—	—	—	4.00	4.00	4.00
Machine maintenance	32.00	30.00	27.25	30.50	32.00	28.00	21.50	20.00	18.00
Haul/dry	16.50	13.35	9.45	4.40	3.50	2.40	4.70	3.90	2.70
Miscellaneous	7.01	6.30	5.45	5.25	4.90	4.72	3.27	3.05	2.63
Interest	8.10	7.28	6.30	6.06	5.66	5.45	3.78	3.52	3.04
Total	149.35	133.59	114.81	97.28	92.47	85.58	72.53	67.50	58.23
Income over variable cost	106.80	75.56	33.24	162.32	114.03	56.02	54.37	37.80	14.67
Labor (hours)	3.4	3.15	3.0	3.2	3.1	3.0	1.6	1.5	1.4
Machinery depreciation plus labor	57.00	55.75	55.00	56.00	55.50	55.00	48.00	47.50	47.00
Return to land	49.80	19.81	−21.76	106.32	58.53	1.02	6.37	−9.70	−32.33

Table 6. Legume and grass hay and pasture budgets by land capability class, medium price scenario, northern Missouri.

Item	Legume and Grass Hay				Pasture				All Soil Types, Minimum-Input Fescue
	Land Capability Class				Land Capability Class				
	IIe	IIIe	IVe	VIe	IIe	IIIe	IVe	VIe	
Yield (bushel or AUM*/acre)	3.6	2.9	2.2	1.9	7.3	6.4	5.4	5.0	3.0
Price ($/ton or AUM)	65.00	65.00	55.00	55.00	7.00	7.00	7.00	7.00	7.00
					$/acre				
Gross income	234.00	188.50	121.00	104.50	51.10	44.80	37.80	35.00	21.00
Variable costs									
Establishment	29.00	27.00	11.00	11.00	5.00	5.00	5.00	4.00	4.00
Fertilizer, lime	34.75	29.76	19.92	17.69	38.83	34.70	29.82	26.68	6.00
Crop chemicals and supplies	10.00	10.00	7.00	7.00	2.00	2.00	2.00	2.00	1.00
Machine maintenance	47.00	42.00	32.00	31.25	2.00	2.00	2.00	2.00	2.00
Miscellaneous	3.00	3.00	3.00	3.00	—	—	—	—	—
Interest	6.81	6.15	4.01	3.85	2.63	2.40	2.14	1.91	.72
Total	130.56	117.91	76.93	73.79	50.46	46.10	40.96	36.59	13.72
Income over variable cost	103.44	70.59	44.07	30.71	.64	−1.30	−3.16	−1.59	7.28
Labor (hours)	10	9.0	6.0	6.0	1.5	1.5	1.5	1.5	1.0
Machinery depreciation plus labor	90.00	85.00	70.00	70.00	7.50‡	7.50‡	7.50‡	7.50‡	5.00‡
Return to land	13.44	−14.41	−25.93	−39.29	−6.86	−8.80	−10.66	−9.09	2.28

*Animal unit month.
†Legume is alfalfa for classes II and III and red clover for IV and V.
‡Labor only.

northern Missouri. Unfortunately, soybeans also add to the potential for excessive erosion on these soils. If soybeans are removed from the crop rotation for the purpose of erosion control, no profitable alternatives remain under the low price scenario.

Note the projected returns to land and management for individual crops under all three price projections (Table 9). As price levels increase, the window of profitability expands. Several crop alternatives become viable on class II and III land for the medium price projection. Land in classes IV and VI can most profitably be used as low-input pasture.

Finally, under the high price projection, corn, soybeans, and wheat generate appreciable returns to land and management, especially for land classes II and III. Again, low-input pasture is a viable alternative for even the least-productive land capability classes.

Competitive advantage of soybean production. The budgets show the competitive advantage of soybeans over corn, wheat, and forages for all selected price scenarios. Most Missouri upland soils, with the exception of the deep loess adjacent to the Missouri and Mississippi Rivers, have solum conditions that restrict root growth. The restrictions include clay texture B horizons (''claypans''), low pH, and shallow depth to bedrock. Coupled with Missouri's climate, which historically results in low rainfall during the hot months of July and August, drought conditions have impacts on many crops, most more severely than soybeans. One of the hypothesized consequences of conservation compliance is the reduction in the amount of soybeans in many rotations, assuming the soil conservation practices used in this study. Nevertheless, a few farmers can be expected to forego USDA program benefits. The result will be a greater emphasis on soybean production and potentially greater erosion.

Economics of compliance alternatives. When conservation compliance takes effect in 1990, crop planting decisions first must take into account soil erosion control and then profitability if producers want to receive USDA program benefits. To illustrate the impact of the compliance constraint, consider the relative profitability of rotations by conservation practice and price scenario (Table 10). Higher returns to land and management, *exclusive* of the cost of conservation practice, can be expected as row-crop production intensifies. Likewise, note that the returns decrease with a given

conservation practice as the land quality shifts from class II to class VII. Also, the cropping options that are both profitable and acceptable for soil erosion goals diminish quickly with increasing class number. For example, class III land represents a condition where profitable land use teeters between low-input pasture and crop production, depending on crop price. Clearly, the profitable alternatives available for land classes III and higher are quite limited as a consequence of conservation compliance, and the returns to land and management are quite low.

Economics of alternative conservation systems. Alternative conservation systems allow soil erosion to exceed T for the purpose of avoiding undue financial hardships in conservation compliance planning. In Missouri, alternative conservation systems are acceptable for compliance planning if erosion is kept at or below 11 t/ha/yr (5 tons/acre/year) or the amount of soil erosion that would occur under a cropping practice of continuous corn planted no-till, up-and-down slope with 70% residue remaining immediately after planting, whichever is higher (5). Depending on soil type, the allowable soil erosion rates do not exceed 11 t/ha/yr until a slope of 7-8% is reached. Although the alternative systems allow more intensive row-crop production on steeper slopes, compared to planning for T, no crop is profitable (Table 9). In essence, the alternative systems allow for the selection of cropping practices that "lose" less money. An exception might be the deep loess soils immediately adjacent to the Missouri and Mississippi rivers. These might generate a small profit.

We did not consider no-till cropping as a management practice in this study. No-till, continuous soybeans planted on the contour is an acceptable alternative cropping system on class II; class III; and, with the addition of a cover crop, class IV and class VI land. Producers who learn how to produce crops under no-till will find that conservation compliance will not affect their crop rotation decisions.

Policy implications

Several policy implications can be drawn from this analysis. They are based on reducing soil erosion to T, or the alternative systems mentioned above, and for soil-climatic conditions similar to northern Missouri. Four deserve elaboration:

Table 7. Corn, soybean, and wheat budgets by land capability class, high price scenario, northern Missouri.

	Corn			Soybeans			Wheat		
	Land Capability Class			Land Capability Class			Land Capability Class		
Item	*IIe*	*IIIe*	*IVe*	*IIe*	*IIIe*	*IVe*	*IIe*	*IIIe*	*IVe*
Yield (bushels/acre)	109	89	63	44	35	24	47	39	27
Price ($/bushel)	3.00	3.00	3.00	7.50	7.50	7.50	3.45	3.45	3.45
					$/acre				
Gross income	327.00	267.00	189.00	330.00	262.00	180.00	162.15	134.55	93.15
Variable costs									
Seed	17.75	16.00	14.00	12.00	12.00	12.00	12.00	12.00	12.00
Fertilizer	43.99	36.66	28.36	18.07	13.41	12.01	23.28	21.03	15.86
Chemicals	19.00	19.00	19.00	21.00	21.00	21.00	—	—	—
Machine hire	5.00	5.00	5.00	—	—	—	4.00	4.00	4.00
Machine maintenance	32.00	30.00	27.25	30.50	32.00	28.00	21.50	20.00	18.00
Haul/dry	16.50	13.35	9.45	4.40	3.50	2.40	4.70	3.90	2.70
Miscellaneous	7.01	6.30	5.45	5.25	4.90	4.72	3.27	3.05	2.63
Interest	8.10	7.28	6.30	6.06	5.66	5.45	3.78	3.52	3.04
Total	149.35	133.59	114.81	97.28	92.47	85.58	72.53	67.50	58.23
Income over variable costs	177.65	133.41	74.19	232.72	169.53	94.42	89.62	67.05	34.92
Labor (hours)	3.4	3.15	3.0	3.2	3.1	3.0	1.6	1.5	1.4
Machinery depreciation plus labor	57.00	55.75	55.00	56.00	55.50	55.00	48.00	47.50	47.00
Return to land	120.65	77.66	19.19	176.72	114.03	39.42	41.62	19.55	−12.08

Table 8. Legume and grass hay and pasture budgets by land capability class, high price scenario, northern Missouri.

	Legume and Grass Hay				Pasture				*All Soil Types, Minimum-Input Fescue*
	Land Capability Class				Land Capability Class				
Item	*IIe*	*IIIe*	*IVe*	*VIe*	*IIe*	*IIIe*	*IVe*	*VIe*	
Yield (bushels or AUM*/acre)	3.6	2.9	2.2	1.9	7.3	6.4	5.4	5.0	3.0
Price ($/ton or AUM)†	70.00	70.00	60.00	60.00	8.00	8.00	8.00	8.00	8.00
					$/acre				
Gross income	252.00	203.50	132.00	114.00	58.40	51.20	43.20	40.00	24.00
Variable costs									
Establishment	29.00	27.00	11.00	11.00	5.00	5.00	5.00	4.00	4.00
Fertilizer, lime	34.75	29.76	19.92	17.69	38.83	34.70	29.82	26.68	6.00
Crop chemicals and supplies	10.00	10.00	7.00	7.00	2.00	2.00	2.00	2.00	1.00
Machine maintenance	47.00	42.00	32.00	31.25	2.00	2.00	2.00	2.00	2.00
Miscellaneous	3.00	3.00	3.00	3.00	—	—	—	—	—
Interest	6.81	6.15	4.01	3.85	2.63	2.40	2.14	1.91	.72
Total	130.56	117.91	76.93	73.79	50.46	46.10	40.96	36.59	13.72
Income over variable cost	121.44	8.509	85.09	40.21	7.94	5.10	2.24	3.41	10.28
Labor (hours)	10	9.0	6.0	6.0	1.5	1.5	1.5	1.5	1.0
Machinery depreciation plus labor	90.00	85.00	70.00	70.00	7.50‡	7.50‡	7.50‡	7.50‡	5.00‡
Return to land	31.44	.09	−14.93	−29.79	.44	−2.40	−5.26	−4.09	5.28

*Animal unit month.
†Legume is alfalfa for classes II and III and red clover for IV and V.
‡Labor only.

First, the impact will be lower economic returns to land and management and, subsequently, to the value of the land itself. This will be especially critical on erodible land in capability classes III and higher. This conclusion is not to say that conservation compliance should "go away." However, it is naive and cruel to work with farmers and landowners on soil conservation and ignore the economic consequences or to assume that conservation compliance will disappear in the near future.

Second, the analysis suggests that class IV, class VI, and possibly class III land will be relegated for economic reasons to low-input (scrub oak and fescue) pasture in the future. This land is the type presently enrolled in CRP for a maximum bid of $65/acre in Missouri. The CRP will have placed an artificially high floor price under this land if this return is capitalized into land values. Under these circumstances, land values would be determined by such things as speculation and nonagricultural uses. Some land would likely revert to the public domain due to nonpayment of real estate taxes. Given the length of the CRP and its low labor requirements, farmers are likely to have down-sized their machinery complement so that most of this return likely is attributed to land. What will happen to the value of this land at the end of the CRP?

Third, soybeans have tended to be the dominant crop on erodible soils in northern Missouri and are extremely important to the Missouri agricultural economy. If these erodible soils are to be kept in profitable crop production other than grass and trees, producers will have to use new cultural practices, such as no-till soybeans, and new crops, including nontraditional crops.

Fourth, soil conservation programs have economic implications on farm income that, in turn, extend into rural economies. There is no doubt that stewardship of the soil resource is deficient, especially on erodible yet profitable land. If present agricultural enterprises are neither consistently profitable nor resource-sustainable, then such alternatives as long-term easements need to be considered as financial means for helping farmers and landowners shift out of an undesirable land use.

Table 9. Projected returns to land and management by land capability class for three price scenarios in northern Missouri.

Crop	Assumed Price	Returns by Land Capability Class IIe	IIIe	IVe	VIe
		$			
Low price scenario					
Corn	$1.90/bushel	0.75	−20.25	−50.11	
Soybeans	$4.75/bushel	55.72	18.78	−26.58	
Wheat	$2.20/bushel	−17.13	−29.20	−45.83	
Legume/grass	60/50*/ton	−4.56†	−28.91†	−36.93‡	−48.79‡
Improved pasture	$6.00/AUM	−14.16	−15.20	−16.06	−14.09
Low-input pasture	$6.00/AUM	−0.72	−0.72	−0.72	−0.72
Medium price scenario					
Corn	$2.35/bushel	49.80	19.81	−21.76	
Soybeans	$5.90/bushel	106.32	58.53	1.02	
Wheat	$2.70/bushel	6.37	−9.70	−32.33	
Legume/grass	65/55*/ton	13.44†	−14.41†	−25.93‡	−39.29‡
Improved pasture	$7.00/AUM	−6.86	−8.80	−10.66	−9.09
Low-input pasture	$7.00/AUM	2.28	2.28	2.28	2.28
High price scenario					
Corn	$3.00/bushel	120.65	77.66	19.19	
Soybeans	$7.50/bushel	176.72	114.03	39.42	
Wheat	$3.45/bushel	41.62	19.55	−12.08	
Legume/grass	70/60*/ton	31.44†	.09†	−14.93‡	−29.79‡
Improved pasture	$8.00/AUM	0.44	−2.40	−5.26	−4.09
Low-input pasture	$8.00/AUM	5.28	5.28	5.28	5.28

*Higher figure is alfalfa/grass hay; lower, red clover/grass hay.
†Legume is alfalfa.
‡Legume is red clover.

Table 10. Return to land and management for the most profitable rotation permitting tolerable soil loss (T) by land capability class and price scenario for each of four management practices on northern Missouri soils.

Item	Return by Land Capability Class IIe	IIIe	IVe	VIe
	$/acre/rotation year			
Farming without regard to soil erosion				
Rotation	Continous soybean	Continuous soybean	Continuous soybean	Continuous soybean
Price scenario				
Low	55.72	18.28	−0.72*	−0.72*
Medium	106.32	58.53	1.02	2.28*
High	176.72	114.03	39.42	5.28*
Farming on contour				
Rotation	Corn, soybeans, wheat	Corn, soybeans wheat, 2 years meadow	Soybeans, wheat, 3 years meadow	Continuous meadow
Price scenario				
Low	13.11	−0.72*	−0.72*	−0.72*
Medium	54.16	14.64	2.28*	2.28*
High	113.00	44.36	8.64	5.28*
Contour plus conservation tillage				
Rotation	Corn, soybeans	Corn, Corn, soybeans, wheat, meadow	Soybeans, wheat, 2 years meadow	Continuous meadow
Low	28.24	−0.72*	−0.72*	−0.72*
Medium	78.06	18.15	2.28*	2.28*
High	148.69	67.84	9.48	5.28*
Conservation tillage plus terraces				
Rotation	Continuous soybeans	Corn, corn, soybeans	Soybeans, wheat, meadow	Continuous meadow
Price scenario				
Low	55.72	−0.72*	−0.72*	−0.75*
Medium	106.32	32.72	2.28*	2.28*
High	176.72	89.78	10.87	5.28*

*Low-input pasture (minor fence repair, pickup depreciation).

REFERENCES CITED

1. Bay, D. M. 1985. *Missouri agricultural statistics by counties and districts 1970-1982.* Mo. Crop and Livestock Reporting Serv., Columbia.
2. Blase, Melvin G. 1988. *The economic impact of conservation compliance.* In *Proceedings, Water Quality and Soil Conservation: Conflicts of Rights and Issues.* Spec. Rpt. 394. Agr. Exp. Sta., Univ. Mo., Columbia. pp 72-81.
3. McCormack, D. E., K. K. Young, and L. W. Kimnberlin. 1982. *Current criteria for determining soil loss tolerance.* In *Determinants of Soil Loss Tolerance.* Spec Pub. 45. Am. Soc. Agron., Madison, Wisc. pp. 95-111.
4. Soil Conservation Service. 1973. *Land-capability classification.* Agr. handbk. No. 210. U.S. Dept. Agr., Washington, D.C.
5. Soil Conservation Service. 1989. *Guidesheet for alternative conservation systems for cropland.* Mo. Field. Off. Tech. Guide. Columbia.
6. University of Missouri. *Missouri farm planning handbook.* Man. 75. Rev. 2/86. Coll. Agr., Ext. Div., Columbia. □

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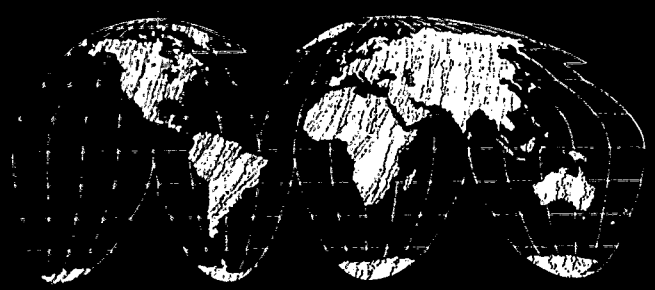

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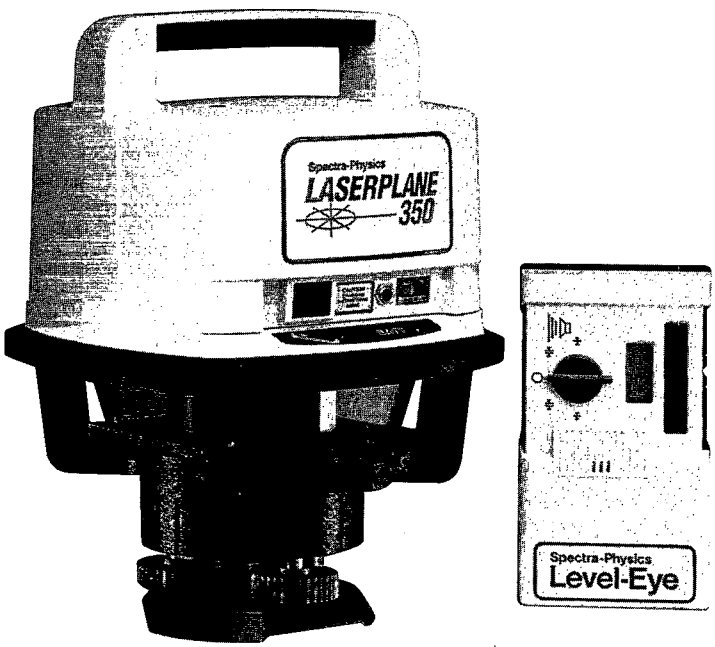

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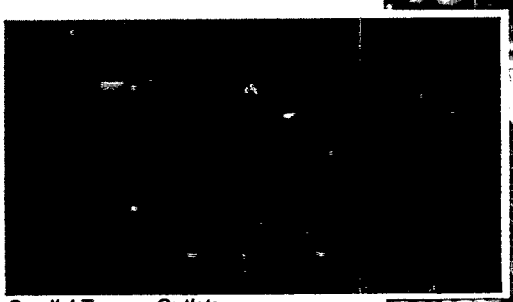

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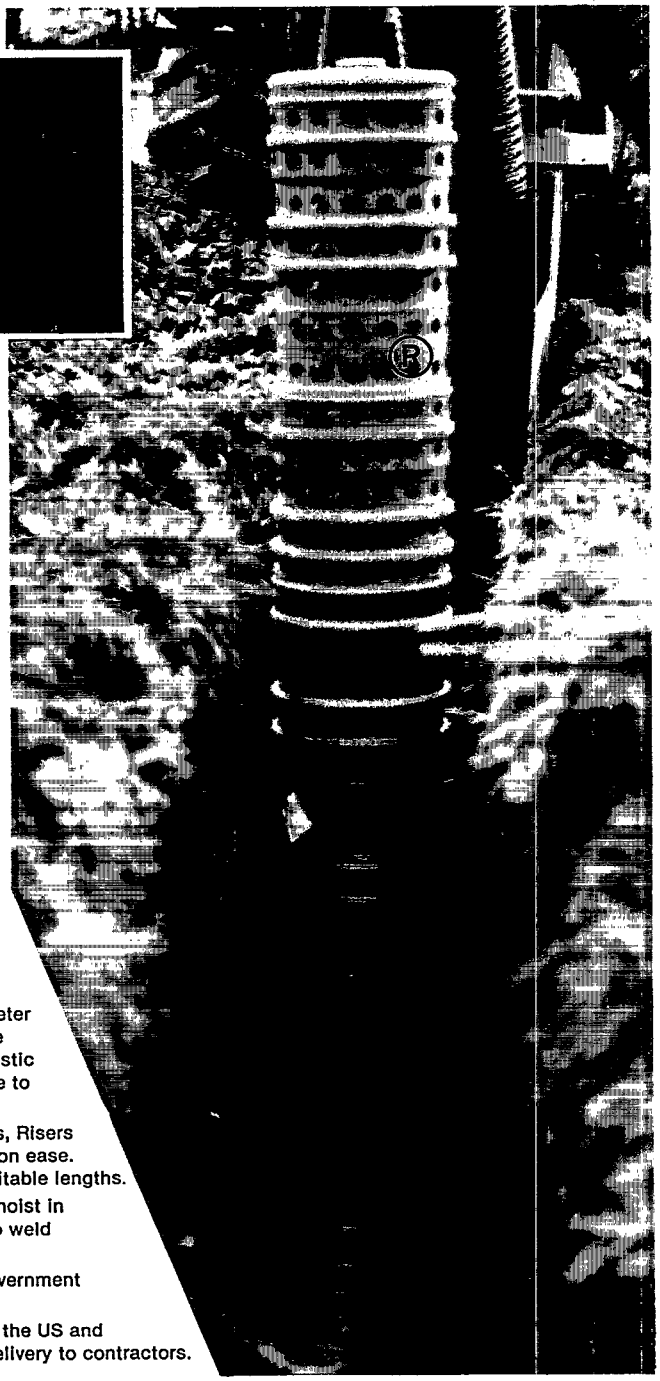

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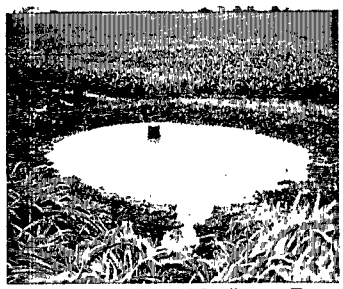

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