HENRY A. WALLACE INSTITUTE
FOR ALTERNATIVE AGRICULTURE

An Agenda for Research on the Impacts of Sustainable Agriculture *

Assessment and Recomendations of a Panel of Social Scientists

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* Deliberations of a panel of social scientists convened by the Institute for Alternative Agriculture, as interpreted and summarized by Neill Schaller, Associate Director of the Institute. The views reported do not necessarily represent those held by every panelist.

Acknowledgments

We are grateful to the following social scientists who came to the Institute in January 1991 to examine the state of research on the impacts of sustainable agriculture and to recommend ways to overcome its current limitations:

Dr. Frederick H. Buttel, Cornell University; Dr. Paul Faeth, World Resources Institute; Dr. William D. Heffernan, University of Missouri; Dr. Glenn A. Helmers, University of Nebraska; Dr. Stanley R. Johnson, Iowa State University; Dr. Linda K. Lee, University of Connecticut; Dr. Kent D. Olson, University of Minnesota; and Dr. Katherine Reichelderfer, Resources for the Future.

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Executive Summary

Growing support in the U.S. for an environmentally and economically sustainable agriculture is increasing the interest of many people in the likely impacts of widespread adoption of such an agriculture. Research to provide answers is limited and not without serious deficiencies. As a result, personal and public policy decisions affecting, and affected by, adoption of sustainable farming could be ill-informed.

The Institute for Alternative Agriculture, concerned about the lack of sound information on likely impacts of sustainable farming, convened a small group of social scientists in January 1991 to examine the state of research on such impacts and to recommend ways to overcome its current limitations.

The panel, which looked at a sample of recent studies, concluded that contemporary research on impacts is basically incompatible with the concept and nature of sustainable agriculture as commonly defined. The incompatibility shows up especially in the choice of indicators used to describe the impacts of its adoption, in

the methods and assumptions generally used in research, and the estimation of crop yields that would be obtained if there were a major shift to sustainable farming.

Indicators. Contemporary research on impacts has emphasized the economic performance of the agricultural sector rather than the impacts of agriculture on the environment. Indicators such as farm production, exports, food prices, and the like, while important, are nevertheless incomplete. Indeed, research reports often interpret the impacts they estimate in ways that suggest a lack of understanding of society's apparent interest in the balancing of environmental and health protection with traditional economic goals of income and growth.

The panel recommends that the research community, led by social scientists and their professional associations, embark on a major effort to identify and create suitable indicators that will adequately reflect public interest in a sustainable agriculture. Useful indicator ideas may be found in unrelated fields. The indicators to be created should shed light on the tradeoffs and complementarities between environmental and economic impacts, as well as the relationships between economic and social consequences for farmers and rural communities.

Research Methods and Assumptions. Contemporary research on impacts of any major change in agriculture is constrained by a number of methodological limitations and questionable assumptions. But these become more disturbing when the purpose is to estimate the impacts of a sustainable agriculture. Specialization and the view of production as a process of converting inputs into separable outputs — important characteristics of conventional agriculture — lend themselves to contemporary economic impact analysis more easily than does the holistic, systems character of sustainable farming.

Assumptions commonly used in contemporary economics research that the past is a useful guide to the future and that the value of things today invariably exceeds their value in future years are severe limitations when researching sustainable agriculture.

The panel urges social scientists and their associations to seriously study and implement ways to overcome these limitations, including the development and use of new theories, modeling procedures, and data to more accurately depict the nature and complexity of sustainable farming.

Yield Estimation. Selected studies show that if farmers did not use synthetic chemical pesticides and fertilizers, U.S. crop yields would decline in the neighborhood of 50 percent, depending on the crop. These estimates are especially important because they shape numerous other indicators used to describe the impacts of a change in farming practices, such as land needed for production, food prices, exports, and soil erosion. They are also suspect.

A major reason for questioning estimates of substantial yield losses is that professionals making such estimates simply do not have as much knowledge of sustainable practices and associated yields, especially organic or chemical-free practices, as they do about conventional methods and yields. They also tend to give too little credence to yield-cushioning effects that could accompany adoption of sustainable practices, such as the development of new technologies and services, and farmers' own learning experiences.

The panel urges the research community to develop and test better ways to estimate the yields attainable through sustainable farming. These might include more effective use of case studies, farmer surveys, expert judgments, and plant growth or "process" models.

An Agenda for Research on the Impacts of Sustainable Agriculture

Background

Few issues have aroused public concern in recent years more than the unforeseen and undesirable effects of today's agriculture on natural resources, environmental quality, and human and animal health. Specialization and dependence of conventional agriculture on off-farm inputs, especially synthetic chemical pesticides and fertilizer, have boosted food production to higher and higher levels. But costs have been incurred in the process, such as persistent soil erosion, groundwater contamination, loss of genetic diversity, pesticide residues in food, loss of fish and wildlife, and growing uncertainty about the future productivity and profitability of farming itself.

As a result, support grows among both farmers and nonfarmers for an agriculture that will continue indefinitely to be productive and profitable, conserve resources, protect the environment, and enhance the health and safety of the citizenry. That ideal is now widely referred to as a "sustainable agriculture.

This special report deals with the question, If sustainable farming practices were to be widely adopted by farmers, what would be the impacts? People need to know. They want to understand the benefits and costs associated with adoption of sustainable agriculture, including who will benefit and who will bear the costs. They want to be able to identify, and thereby try to avert, unforeseen and unwanted effects on the performance of agriculture and on the environment. Knowledge of the likely implications of sustainable agriculture could also help to define with increased clarity the goals of agricultural sustainability.

Thus far, research on the impacts of sustainable agriculture has focused mainly on the feasibility and effects of potentially sustainable practices at the farm level.[1] Few studies have examined the likely effects of their adoption for the Nation as a whole or for different regions. The void in information is all too often filled by guesses and unsubstantiated claims. Some of these imply that widespread adoption of sustainable farming could solve most of agriculture's environmental and economic problems, others that it would have dire consequences for food production and the well-being of many people.[2]

Even research that is presented as scientific can be found wanting due to inappropriate analytical techniques and lack of empirical content. While researchers customarily acknowledge the limitations of their work, more often than not their explanations are seen and understood only by a handful of fellow researchers, not by the general public. Moreover, newspaper articles and other media reports on these research findings, though reaching a broader public, are seldom inclined to devote much space to limitations of the research.[3] This may lead to a substantial risk that research estimates of the impacts of sustainable agriculture will foster public confusion and misunderstanding rather than provide the information needed to make well-informed decisions.

Addressing the Problem

The Institute for Alternative Agriculture, aware of the need for sound information and concerned about the risk of public misunderstanding, invited a panel of leading social scientists to the Institute in January 1991 to examine the state of research on the implications of sustainable farming and to develop recommendations for the design and conduct of such research. The panel included:

- Frederick H. Buttel, Professor of Rural Sociology, Cornell University;
- Paul Faeth, Associate, World Resources Institute;

- William D. Heffernan, Professor of Rural Sociology, University of Missouri;
- Glenn A. Helmers, Professor of Agricultural Economics, University of Nebraska;
- Stanley R. Johnson, Director of the Center for Agricultural and Rural Development, Iowa State University;
- Linda K. Lee, Visiting Associate Professor of Agricultural and Resource Economics, University of Connecticut;
- Kent D. Olson, Assistant Professor of Agricultural and Applied Economics, University of Minnesota;
- Katherine Reichelderfer, Senior Fellow, Resources for the Future; and
- Neill Schaller, Associate Director, Institute for Alternative Agriculture, who served as panel moderator.

The panel's deliberations drew on the members' substantial knowledge and personal research on the subject as well as their brief review of selected studies, commentaries, and articles. This report summarizes the group's assessment and recommendations.

Among the sources examined were three studies designed specifically to estimate the aggregate impacts of sustainable farming on agricultural production, resource use, food prices, and other indicators. These studies, summarized in an appendix to this report, are:

- Helmers, Glenn A., Azzeddine Azzam, and Matthew F. Spilker, ***U.S. AGRICULTURE UNDER FERTILIZER AND CHEMICAL RESTRICTIONS*** (1990);
- Knutson, Ronald D., C. Robert Taylor, John B. Penson, and Edward G. Smith, ***ECONOMIC IMPACTS OF REDUCED CHEMICAL USE*** (1990); and
- Olson, Kent D., James Langley, and Earl O. Heady, ***WIDESPREAD ADOPTION OF ORGAMC FARMING PRACTICES: ESTIMATED IMPACTS ON U.S. AGRICULTURE*** (1982).

Another study by Paul Faeth and associates (1991) at World Resources Institute was of interest to the panel because it suggested ways to begin to overcome some of the problems of researching sustainable agriculture. Entitled ***PAYING THE FARM BILL: U.S. AGRICULTURAL POLICY AND THE TRANSITION TO SUSTAINABLE AGRICULTURE***, this study is also summarized in the appendix.

The Panel's Assessment and Recommendations

The panel, rather than preoccupy itself with limitations of available research, tried to consider what might be done to overcome those limitations. Other professionals have discussed the limitations in detail. For example, the Knutson study has been thoroughly critiqued in recent issues of ***Choices***, a magazine published by the American Agricultural Economics Association.[4]

The panel concluded that contemporary research approaches used to appraise the effects of conventional agriculture are ill-suited to the task of estimating the impacts of sustainable agriculture. The two farming scenarios are too dissimilar. The incompatibility is revealed primarily in three characteristics of the research:

1. The choice of **indicators** used to describe the impacts of sustainable agriculture (including indicators of effects on natural resources and the environment, health, and safety, as well as economic and social well-being);

2. The **methods and assumptions** used in the research; and

3. The specific task of estimating technical coefficients, particularly crop yields, that would accompany the adoption of sustainable farming practices.

Each of these limitations may be due to the nature of existing research tools or data, to the way researchers actually design and conduct the research, or to both.

Indicators

The Problem

The panel felt that public interest in the sustainability of agriculture is not adequately described by available indicators of agriculture's performance. Traditional indicators such as yields, production, the number of people fed by one farmer, farm income, food prices, and exports are not wrong, but they are incomplete. They fail to reflect the central theme of sustainability which holds that the quantity and quality of natural resources, the state of the environment, and the health and safety of people have an importance equal to that of production and profit and, indeed, may have profound effects on the latter over the long run.

The problem is twofold. Not only has research typically emphasized impacts on the agricultural sector, but economists have focused on economic impacts while physical scientists have measured the physical effects. Disciplinary specialization is one reason for this fragmentation, which might be overcome through imaginative team research. Another reason could be the desire on the part of researchers to single out for measurement those effects which they believe have been neglected in other studies.

To illustrate, the Knutson study reports at the outset that environmental benefits and costs are amply treated elsewhere, and that therefore it is the task of their study to measure and report the economic benefits that agricultural chemicals have made possible.[5] Unfortunately, that strategy also tends to foster a separation, if not competition, between economic and environmental benefits when the real need is for indicators to clearly portray the tradeoffs and the complementarities between them.

Many of the indicators that could help to describe the impacts of sustainable farming simply do not exist. For instance, there is no current indicator to describe and monitor the number of farmers who become ill when applying chemical herbicides. Nor are there socioeconomic indicators, aside from demographic and employment measures, to adequately describe the impacts of adoption of sustainable farming on the well-being and the sustainability of rural communities.

Indicators invariably have different meanings and a different importance to different interest groups. Most people will be more interested in those indicators that best describe the direct consequences of a change in farming practices for them personally. Therefore, one way to overcome the problem of inadequate indicators in impact research is simply to expand the number of indicators measured.

The interpretation of the value or other meaning of traditional indicators is a related cause for concern. Most indicators carry connotations of goodness and badness. Those that fit the conventional emphasis on production and economic well-being are a case in point. For example, higher yields and exports are regarded as good.

Higher food prices are not. The tone and choice of words in contemporary research reports often reveal the traditional values attached to these measures. In contrast, people whose thinking is more attuned to the meaning of sustainability will point out that what is considered good, or bad, in the conventional way of thinking may be just the opposite when seen from the perspective of sustainability.

As an example, most proponents of sustainable agriculture will feel that high yields and larger exports are not necessarily good if their attainment causes soil erosion and the loss of future productivity. Nor should one cite as an unqualified success the fact that American consumers spend less and less of their income on food. Indeed, the efficiency of conventional agriculture may be partly an illusion when one considers that the price people pay for food does not include many environmental and social "costs" incurred in its production.

Recommendations

- **The research community must begin in earnest to identify and create indicators that will adequately describe impacts of sustainable agriculture of interest to the public.** The concerns of all people potentially affected materially by adoption of sustainable agriculture must be taken into account in the process of developing those indicators. The Faeth study suggests a potentially useful direction to take. By combining into a single indicator the dollar value of farm production and the costs of resource damage inadvertently caused by production, the research begins to respond to the breadth of interest in agricultural sustainability.

- **Social scientists must assume much of the task of developing suitable indicators.** While the identification and measurement of impacts requires major contributions of physical and biological scientists, social scientists should have both the skills and the calling to synthesize the full set of indicators needed to describe the impacts of sustainable agriculture. Accordingly, the American Agricultural Economics Association, the Rural Sociological Society, and other social science associations should lead a bold endeavor not only to create imaginative new indicators but to set in motion the process of developing the data to permit the measurement of those indicators.

- **The indicators needed must reflect not only economic and environmental effects but also the economic and social consequences of agricultural sustainability.**

- **The creation of new indicators should recognize and perhaps build on similar efforts in other and often seemingly unrelated fields.** Researchers designing new measures to describe the impacts of sustainable agriculture may find unexpected and fruitful leads in the development of indicators such as the wind-chill index and those used to measure dietary status or to evaluate advertising.

Research Methods and Assumptions

The Problem

Research on the aggregate impacts of a shift to sustainable agriculture probably would not be possible without the use of simplifying models and assumptions about the real world. Models, whether mathematical or simply reasoned descriptions of behavior, make research manageable and its results intelligible. The obvious disadvantages of simplifying models and assumptions are that they inevitably constrain the meaning and interpretation of research findings. This limitation applies to research on the impacts of any change in farming, not just sustainable agriculture. Still, the panel felt that the limitations of methods and assumptions found in

contemporary research are more serious when the purpose is to estimate impacts of sustainable farming than when they are used to analyze the effects of conventional agriculture.

These limitations are notably disturbing because research findings are shaped, more than most people realize, by the researcher's choice of methods and assumptions, as well as by the data used in the research. In fact, the kinds and magnitudes of estimates of agricultural and environmental impacts made by researchers can often be anticipated by inspecting the methods and assumptions used in their studies.

The importance of assumptions is well illustrated by the sample of studies reviewed by the panel. Both the Knutson and Olson studies estimate the impacts of farming; both assume zero use of synthetic chemical pesticides and fertilizers. However, research is often more useful when it estimates impacts not just for extreme scenarios but also for a range of alternatives. The all-or-nothing approach is especially troublesome when the issue is as sensitive as that of chemical use in agriculture.

Many people, in fact, question the realism of assuming zero use of farm chemicals for all of agriculture. Others might argue that it was chosen to dramatize the negative impacts of a shift away from conventional farming. The Knutson and Olson studies state that the real reason was to make the research more manageable. If so, the assumption required estimates of yields that, due to limited nationwide experience with chemical-free or organic farming, are far more difficult to obtain than if one were to assume a less restrictive scenario. Thus, the gain in manageability came at the expense of reduced confidence in the research results.

The study led by Helmers did not assume zero use of farm chemicals. Rather, it used information about the substitutability between chemical and other production inputs to derive estimates of impacts of different farming approaches. In so doing, the research recognizes that the mix of inputs used in sustainable agriculture is apt to be quite different from that used in conventional farming.

At the same time, the Helmers study is subject to another limitation which applies to much of the research done on impacts of future trends and scenarios that are expected to differ significantly from those of the past. This is the limitation that arises when the research methods require the use of statistical analysis of historical or currently observed data. The underlying assumption that the past is a useful guide to the future does not fit sustainable farming nearly as well as it does conventional agriculture.

Perhaps the most fundamental reason why research methods and assumptions commonly used in contemporary studies are incompatible with sustainable agriculture is that they do not recognize and accurately represent the nature and complexity of sustainable farming systems. Conventional farming is also complicated, but researchers may not be too far off base when they treat it as a technical process of converting inputs into a few, independent outputs. Anyone familiar with Midwest farms on which production of continuous corn or corn in rotation with soybeans is common can see the appropriateness of that view and, therefore, the relevance of contemporary research methods and assumptions to conventional farming.

But sustainable agriculture is different. The specific farming practices that will best meet the criteria of sustainability are yet to be determined with confidence, and even then will vary from place to place. Yet, at the heart of the sustainability perspective is the view that soil is not an input but an organism, and that production is not a mechanical process of converting inputs into outputs. A sustainable farm is a holistic "system," one that depends on close collaboration with Nature and recognizes the beneficial synergistic relationships between soil, climate, plants, animals, and farming practices.[6] The environmental and economic impacts of its adoption are not easily understood or estimated by analyzing one part of the system at a time using the convenient research custom of "holding everything else constant."

If it is difficult to capture these interconnections in analyses of the impacts of sustainable agriculture at the farm level, it is even more difficult when the purpose is to estimate aggregate impacts. This is often the case because aggregate impacts are typically derived by modeling relationships between aggregates rather than by building

them up from impacts on individual farms or farm types. Perhaps this helps to explain the marked difference in the reduction of yields associated with reduced use of chemicals estimated in recent farm-level studies versus the reductions estimated in aggregate studies.[7] Farm-level studies of the effects on yields tend to show reductions on the order of 10 percent. In contrast, estimates of yield effects at the aggregate level, as illustrated by the Knutson and Olson reports, are in the 50 percent range.

The incompatibility of contemporary research with sustainable agriculture is further illustrated by the custom of singling out for analysis a specific crop or other farm enterprise, ignoring or treating outside the analysis other crops as well as livestock produced on farms. This custom fits the specialized, monocultural nature of conventional farming far better than it does a sustainable system that involves expanded use of rotations and diversification.

Omitting livestock from analyses of impacts of conventional agriculture may be appropriate, because of the typical separation of livestock production from the production of feed in such an agriculture. Concentrating on feed crops in the analysis may be further justified when environmental effects of farm chemicals are a major concern, as those crops are the largest users of chemicals. However, excluding livestock in analyses of impacts of sustainable farming can cause serious distortions. Not only does it overlook the potential importance of crop-livestock diversification on sustainable farms, it ignores the environmental benefit of moving from concentrations of livestock — a major source of groundwater contamination — to an agriculture that would tend to lessen contamination through dispersion of livestock.

Yet another potential problem with contemporary research is the tendency for economists to assume that farmers maximize "expected profit," or that they act as though they do. The assumption may facilitate the analytical process. It also seems to fit conventional farming better than sustainable agriculture. But even in the case of conventional agriculture, the relevance of the assumption is being questioned by researchers who recognize the need to integrate environmental, health, and safety considerations with profitability.

Finally, an obstacle of profound importance is the implicit assumption in much economic research that the value of things today invariably exceeds their value in the distant future. That assumption, too, is at odds with the meaning of sustainability. The problem goes beyond the matter of choosing a proper discount rate. Sustainability implies that the value of land, for example, could and should be higher in the future, not only because of rising demand for land but because if managed in a sustainable manner it will ensure productivity, profitability, and environmental quality in more distant years.

Recommendations

- **Social science associations, such as the American Agricultural Economics Association and the Rural Sociology Society, should begin a major appraisal of current research approaches used to estimate the impacts of sustainable agriculture and urge their members to develop and test needed improvements.**

- **The nature and complexity of sustainable farming must not be interpreted as an argument against the need for models and modeling.** Indeed, it is quite possible that to effectively estimate the impacts of sustainable farming systems researchers will require far more sophisticated models than those developed so far.

- **New combinations of existing models and modeling strategies may prove especially rewarding.** To the extent that historical, observed data are not appropriate for research on sustainable farming, approaches must be found to generate the required data. The Faeth study suggests as one approach the use of "process" models which can simulate plant growth and its effects to derive estimates of crop yields and productivity losses due to soil erosion.

Yield Estimation

The Problem

Perhaps the most critical step in an analysis of aggregate impacts of a change in farming practices is understanding the technical relationships involved in production and, in particular, estimating yields that would be expected if that agriculture were widely adopted. Yield estimates are especially vital because they shape so many other indicators commonly measured in impact studies — from land use, production, and soil erosion, to food prices and exports.

A major barrier to estimation of yields in a sustainable agriculture is the difficulty of comprehending and capturing the effects of the synergism, noted above, between soil, climate, plants, animals, and farming practices in a sustainable system. It is only natural that researchers familiar with conventional systems and lacking data on the actual yield effects of this synergism, would expect sustainable farming yields to be lower than those of conventional agriculture.

The difficulty of taking those yield effects into account is especially pronounced when researchers are asked to estimate yields assuming zero use of farm chemicals. That was the question posed to 140 land-grant university plant scientists in the Knutson study. While they were encouraged to consider the substitution of rotations, cultivation, and other production practices for chemicals, their estimates of U.S. yields ranged from 32 to 78 percent below conventional yields, depending on the crop.

Lack of familiarity with sustainable practices and yields can also influence the person's expectation of the effects of other developments that might cushion a decline in yields obtained with reduced or zero use of farm chemicals. These could include the development of new and different production technologies, inputs, and agricultural services, as well as farmers' own learning experiences and improved management skills as they shift to sustainable practices.

Yield estimations by Olson and Helmers and their colleagues avoided only some of the obstacles faced in the Knutson study. Both relied on actual historical data, rather than on the judgments of scientists. In the Olson study, yield estimates were based on actual yields in pre-chemical farming years, adjusted for the yield gains through plant breeding and variety improvements. Helmers derived yields from historical relationships between inputs and outputs. But neither study realistically portrays the unique biological, physical, chemical, and human interactions that are so vital to a sustainable agriculture, nor their potential effects on yields.

Recommendations

- **The research community must develop and test new ways to estimate yields that could be achieved in a sustainable agriculture.** The panel identified several approaches worthy of consideration:

    1. **New and effective use of case studies.** Case studies have been traditionally shunned by agricultural economists because of the difficulties of inferring results from individual cases to groups of farms. However, researchers in other fields use them effectively and a reappraisal of their usefulness in agriculture is warranted.

    2. **Use of farmer surveys.** Actual farmer experience may well be the best source of data on yields. The U.S. Department of Agriculture's Low-Input Sustainable Agriculture Research and Education Program, which involves farmers directly, should be considered as a potential framework or future source of appropriate yield data.

3. **More effective use of expert judgment.** The knowledge of research and education professionals, as well as farmers, should continue to be regarded as valuable sources of yield estimates, especially through use of the Delphi or other approaches involving full interaction, testing, and revision of estimates made by knowledgeable persons.

4. **The application of "process" models to generate yields associated with sustainable farming practices.**

- **In addition to, or in lieu of, the estimation of yields directly, researchers could "assume" such yields and proceed then to estimate, and infer from, the associated impacts.** Varying the assumed yields through the use of known parametric procedures could shed useful light on the variability and sensitivity of yield changes on other indicators. The impacts so estimated could also indicate the benefits and costs of adoption of sustainable agriculture, and the value of research, education, and government farm policies.

Closing Comment

The panel's assessment and recommendations, by admission, are partial and preliminary. They are offered with the hope that others, reading them, will be encouraged to pursue a fruitful agenda for research on the implications of sustainable agriculture.

The panel believes that contemporary research on the impacts of sustainable agriculture, so far, has been incompatible with the meaning and nature of sustainable agriculture. The problem is due as much to the way the research has been done as it is to a lack of appropriate tools. Therefore, what is needed first and foremost is a fundamental change in the philosophy and mindset of those who administer and conduct the Nation's agricultural research. This could call for a combination of refinements in existing research techniques and data as well as new paradigms to help researchers apply their skills to questions about agricultural sustainability.

Meeting the challenge could have benefits far exceeding an improved ability to do meaningful research on the impacts of sustainable agriculture. It could greatly expand the capacity and the credibility of the agricultural research community to produce meaningful research on combinations of agricultural, environmental, and health issues, and related policy questions, that will surely be asked in the years ahead.

Appendix

Summaries of Selected Studies Examined by Panel

Studies Estimating Aggregate Impacts of Agricultural Practices

- Helmers, Glenn A., Azzeddine Azzam, and Matthew F. Spilker. ***U.S. Agriculture Under Fertilizer and Chemical Restrictions***. Department of Agricultural Economics, University of Nebraska. Report No. 163, March 1990.

  This study, unlike those led by Knutson and by Olson (below), measures the effects of restricting rather than eliminating the use of chemical inputs. It estimates the resource use and production that would be expected over a 4-6 year period. The analysis considers feedgrains, wheat, and soybeans, along with federal commodity programs affecting their production.

To estimate the effects of restricted chemical use, the researchers used a model of the statistical relationships between prices and production of the commodities, prices and use of inputs, and past substitution between different resource inputs. The model indicates which resources would replace chemicals if the latter were restricted, and how those changes would affect production.

The analysis shows that, based on past data, U.S. agriculture could adjust to a reduction in the use of chemicals without causing significant reductions in farm production, or major changes in prices and other performance indicators. More labor and other non-chemical inputs would be needed. However, a 10 percent reduction in chemical inputs would be expected to decrease wheat output by only 1.26 percent and soybean production by 2.2 percent, and would have little effect on feedgrain production. Market prices would rise only modestly.

- Knutson, Ronald D., C. Robert Taylor, John B. Penson, and Edward G. Smith. ***Economic Impacts of Reduced Chemical Use***. Knutson & Associates, College Station, Texas, 1990.

  This study has received considerable attention in the press and in the agricultural research community (see endnotes 3 and 4). Its stated purpose was to examine the economic impacts of reduced use of synthetic chemical pesticides and nitrogen fertilizer on crop yields, production, food prices, farm income, commodity exports, land use and values, and other indicators of the performance of agriculture. However, the study actually examined the effects of eliminating entire combinations of synthetic chemicals (herbicides, insecticides, fungicides, and inorganic nitrogen). Reasons given for investigating only the zero chemical scenario were that it was more manageable and that the results would be useful as indications of the outer boundary of possible outcomes.

  Agriculture was defined to include eight crops which, according to the authors, account for 75 percent of the chemical pesticides used in the United States and 70 percent of the inorganic nitrogen fertilizer. The crops were corn, wheat, soybeans, sorghum, barley, cotton, rice, and peanuts. Livestock were recognized in the study only through their role as consumers of major crops included in the analysis.

  To quantify impacts, the researchers first asked 140 leading plant scientists at land grant universities around the country to estimate the yields of the eight crops if grown without chemicals. The scientists were to take into account practices that might be substituted for chemicals such as expanded use of rotations, cultivation, and green manures. Agricultural economists at key universities translated the yield estimates and practice changes into costs of production. The data were then analyzed to quantify other performance indicators using models that simulate relationships between costs, resource use, commodity demand and supply, and other economic relationships.

  According to this analysis, farming without chemicals would reduce yields from about 32 percent for corn to about 78 percent for peanuts. The reductions would lead to an increase in annual food prices of more than $400 per household and reduce exports of grain and cotton by 50 percent. Incomes of crop farmers would double, but those of livestock producers would drop by 50 percent, because of higher feed prices. Ten percent more land would be needed to produce crops, which the researchers said would probably increase the risk of soil erosion. Yield and income effects would be more pronounced in the case of crops and regions with more serious pest problems requiring a heavy dependence on chemical pesticides.

- Olson, Kent D., James Langley, and Earl O. Heady. ***Widespread Adoption of Organic Farming Practices: Estimated Impacts on U.S. Agriculture***. Journal of Soil and Water Conservation, January-February 1982, pp. 41-45.

  This study predated today's heightened interest in agricultural sustainability but is still cited as an example of research on the consequences of a major change in agricultural practices. It uses mathematical programming, a technique commonly employed by agricultural economists in recent decades, to estimate yields, acreages, production, farm, and consumer prices. To reflect geographic and farming differences, the nation was divided into 150 regions. As in the Knutson study, the research focused on crops. Yields, costs, and returns were the basic data estimated. Livestock were excluded. Here, too, the purpose was to trace the effects of not using any agricultural chemicals to produce crops.

  Instead of asking plant scientists to estimate expected yields without chemical inputs, the researchers in this case used actual yields from the 1940's (before chemicals were in wide use), adjusted upward for the effects of subsequent plant hybridization and variety improvements. Resulting yield and export estimates were similar to those obtained in the Knutson study.

Study Illustrating Alternative Research Approaches

- Faeth, Paul, Robert Repetto, Kim Kroll, Qi Dai, and Glenn Helmers. ***Paying the Farm Bill: U.S. Agricultural Policy and the Transition to Sustainable Agriculture***. World Resources Institute, Washington, D.C., March 1991.

  Although the purpose of this study was to estimate the "true" benefits and costs of alternative government policies for agriculture, it also illustrates the application of pioneering techniques to estimate the likely impacts of a sustainable agriculture. Using what is called "natural resource accounting," the researchers estimated some of the environmental impacts as well as economic consequences of conventional versus sustainable farming systems.

  The analysis utilizes actual agronomic data from field trials in a sequence of steps including the use of a physical "process" or plant growth model to calculate changes in soil productivity associated with conventional and sustainable farming practices, the application of a farm-level mathematical programming model to estimate the most likely economic outcomes, and a case study approach. The two "cases" are farms in Pennsylvania and Nebraska, chosen because they represent very different circumstances.

  The results show that when the on-farm and off-farm costs of soil erosion are included in the calculation of farm income for Pennsylvania farms (and to a lesser extent, Nebraska farms), resource-conserving practices clearly produce a larger net economic value per acre than do conventional practices.

Endnotes

1. See Lee, Linda K., "Reducing Agricultural Chemical Use: Tradeoffs Among Agricultural Production, Farm Income, and Consumer Food Prices," University of Connecticut, unpublished paper, 1991.

2. As examples of the latter, see pamphlet distributed by ICI Americas, Inc., "Feast or Famine — A Thin Line," undated; and National Association of Agricultural Chemicals, "Tough Questions and Frank Answers — A Candid Approach to Food Safety," April 1989.

3. Press coverage of one of the studies discussed in this report is illustrative. See "Farm Chemical Ban Could Be Costly," in ***The Journal of Commerce***, June 19, 1990; and "Report Blasts Zero Use of Chemicals on Farms," in ***Lubbock Avalanche-Journal***, March 27, 1990.

4. See Ayer, Harry, and Neilson Conklin, "Economics of Ag Chemicals: Flawed Methodology and a Conflict of Interest Quagmire," and Knutson, Ronald D., C. Robert Taylor, John B. Penson, and Edward G. Smith, "Economic Impacts of Reduced Chemical Use," in ***Choices***, Fourth Quarter 1990, pp. 24-31; and Letters in ***Choices***, First Quarter 1991, pp. 40-42. For an earlier, related critique of economics research related to use of chemicals in farming, see Otto Doering, "Fig Leaves for Naked Economists," ***Choices***, Third Quarter 1990, pp. 31-32.

5. Knutson, Ronald D., C. Robert Taylor, John B. Penson, and Edward G. Smith, ***Economic Impacts of Reduced Chemical Use***, Knutson & Associates, College Station, Texas. 1990, pp. iii.

6. For a good discussion of the nature and significance of this synergism, see U.S. Department of Agriculture, ***Report and Recommendations on Organic Farming***, U.S. Government Printing Office, Washington, D.C., 1980, including page 88, Section 7.2.

7. See Lee, Linda K., op. cit., pp. 9 and 11.

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