ESO 1830

The Economics Of An Environmentally Sound Agriculture (ESA)

By
*Luther Tweeten**

Introduction

I have witnessed numerous agricultural movements that made sense at the time but did not wear well. Shortly after World War II, responding to popular appeals, the Cooperative Extension Service and other organizations sponsored numerous clean-plowing contests across the country. The winner left nary a stalk exposed to the elements. Environmentalists of today would be horrified, but at that time the measure seemed proper because the pesky corn borer overwintered in exposed corn stalks.

At issue is the sustainability of the environmental movement. In this paper the latest environmental movement is variously called *alternative agriculture* (AA), *regenerative agriculture* (RA), or *low-input sustainable agriculture* (SA or LISA). If the movement is to succeed, it must do so not just by exhortation but by being environmentally and economically feasible. One conclusion of this paper is that the term "LISA" is transitory but that the search for an *environmentally sound agriculture* (ESA) is lasting. The main purpose of this paper is to assess the economic feasibility of an environmentally sound agriculture. Before doing so, I examine the latest environmental movement, its degree of implementation, and why it will continue to be a divisive issue. The final section outlines elements of public policy to implement ESA.

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The Environmental Movement in Perspective

The market alone will not properly attend to natural and environmental resources. A public role is essential. The environmental movement waxes and wanes, however, because the public has only a limited attention span for calls to serve even worthy objectives such as food, water, and air stewardship. When attention fatigue triumphs, the movement fades but often leaves a residue of benefits. The benefits fall far short of perfection. Hence the movement renews after the public psyche is rested. Succeeding movements typically begin with new leaders, new slogans, and new goals.

Defining Alternative Agriculture

An *environmentally sound agriculture pursues environmental practices as long as incremental social benefits exceed social costs*. On average, it discounts future benefits at the social discount rate. That rate, the real interest rate, historically has averaged 2-3 percent, hence places little premium on present versus future consumption. Some individual farmers have high discount rates, however, and are willing to accept higher current levels of environmental degradation than are acceptable to the nation as a whole.

Alternative agriculture may be defined alternatively as a philosophy or as an operational concept. Alternative agriculturalists emphasize that their approach differs from that of conventional agriculture (CA) mainly in philosophy. Alternative agriculture advocates view the farm as a living organism, not as a factory. Words such as "integrated" or "systems" emphasize that parts of the organism cannot be viewed in isolation but as interconnected parts of the whole. Emphasis is on working in harmony with nature. Emphasis is on conserving natural resources and minimizing use of synthetic chemicals. Conventional agriculturalists take a similar but less extreme view, and emphasize rational appraisal of costs and benefits of alternative means of using that system to achieve desired ends. Many alternative agriculturalists view their system as part of the epic struggle of good (SA) versus evil (CA). In fact, the issue is not that simple. The choice frequently is between two evils such as mechanical control of weeds attended by soil erosion versus chemical control of weeds attended by some groundwater contamination. Choosing between two economic evils is not easy on moral imperative grounds alone. Viewing alternative agriculture as a philosophy or ethic precludes rational evaluation of the system in scientific terms.

As a working concept, *sustainable agriculture* combines sound environmental practices synergistically in a system so that the whole exceeds the sum of the parts. Sustainable agriculture thus defined attempts to integrate four traditional components of agriculture: (1) soil and water conservation dating at least to Teddy Roosevelt in the late 1800s, Franklin Roosevelt in the 1930s, and conservation tillage of the 1970s, (2) prudent synthetic chemical (pesticide and nitrogen fertilizer) use strongly emphasized by the Integrated Pest Management (IPM) programs of the 1970s and 1980s, and more recently by Best Management Practices and Integrated Crop Management programs[1], (3) crop rotations used in 1988 on 80 percent of acres in the seven major crops (USDA, May 1990), and (4) crop-livestock systems (Figure 1). Items (3) and (4) date to the origins of agriculture[2]. Thus the components of alternative agriculture are conventional agriculture. The National Research Council Report on *Alternative Agriculture* (NRC, pp. 136, 137) noted that "many individuals in [land-grant universities and the U.S. Department of Agriculture] have been investigating for years practices and systems that have alternative agriculture applications."

Only when components in Figure 1 are brought together in a *synergistic system* can they properly be called sustainable agriculture. To encourage positive interactions between components in Figure 1 through good management, the Conservation Reserve Program will be expanded with emphasis on water quality and wildlife. The 1990 farm bill (Food, Agriculture, Conservation, and Trade Act) authorized LISA research and extension programs up to $80 million annually, the Integrated Farm Management Program including up to 5 million acres

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[1]Integrated Crop Management (ICM) initiated before passage of the 1990 farm bill is an example of an extension of IPM to include fertilizers and herbicides as well as insecticides and fungicides in a whole farm setting. The pilot program, similar to the Integrated Farm Management Program in the 1990 farm bill, combines cost-share funds from the Agricultural Stabilization and Conservation Service with technical advice from the Soil Conservation Service and Cooperative Extension Service. To be eligible for cost-sharing, farmers must have an approved ICM system designed by an eligible technical expert, and with documentation to show proof of increased efficiency and ecological effects. The ICM system can include field scouting for pests, ridge-till cropping, planting of host crops, soil testing, biological pest control services, grasses and legumes in rotation, cover and green manure crops, leaf tissue analysis, and selected special equipment. If fertilizers and pesticides are priced properly to reflect social costs and not just private costs, ICM might not need public cost-sharing for economic feasibility. However, it is notable that IPM is not very widely used except in fruit and vegetable production despite the fact that it has been available for two decades (see NRC, p. 178).

[2]Rotations are not typical in many situations where profitable alternative crops are not available. Examples include cotton in the Mississippi Delta, rice in California, wheat in Oklahoma, and irrigated corn in Nebraska.

(see ICM, footnote 1), the agricultural Water Quality Incentives Program (WQIP) enrolling up to 10 million acres, and the Wetlands Reserve Program enrolling up to 1 million acres in paid easements of 30 or more years to enhance wildlife habitat.

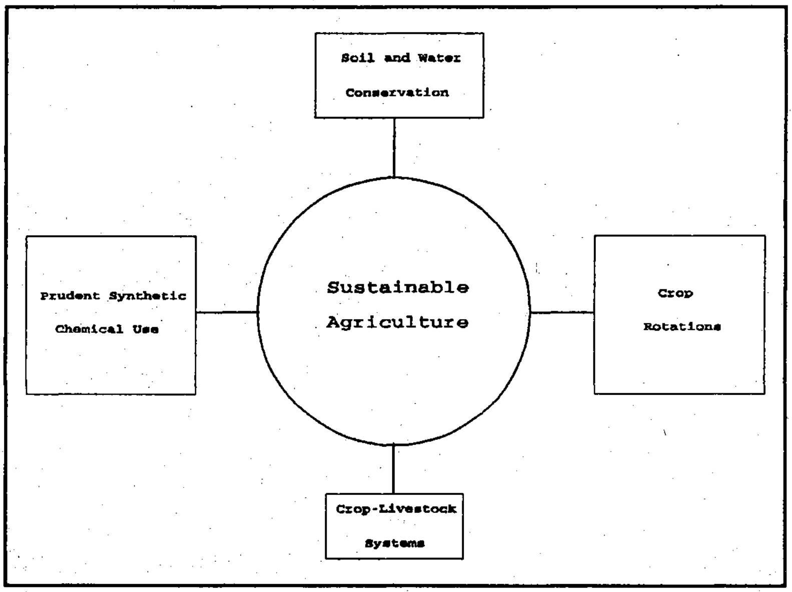

Figure 1. Components of Sustainable Agriculture Systems.

Progress Towards Implementation

At issue is how far American farmers have progressed to implement sustainable agriculture. The following graphs chart progress in implementing components of SA to protect the environment and to raise profits. Conservation tillage is practiced on nearly 100 million acres and is rising (Figure 2). Partly because of proven practices such as ridge tillage and conservation tillage along with selective herbicide use, farm power requirements have declined. Sharp cuts in gasoline and to a lesser extent in liquified petroleum fuel use along with nearly stable use of diesel fuel in recent years (see Figure 3) have markedly reduced fuel use per unit of output.

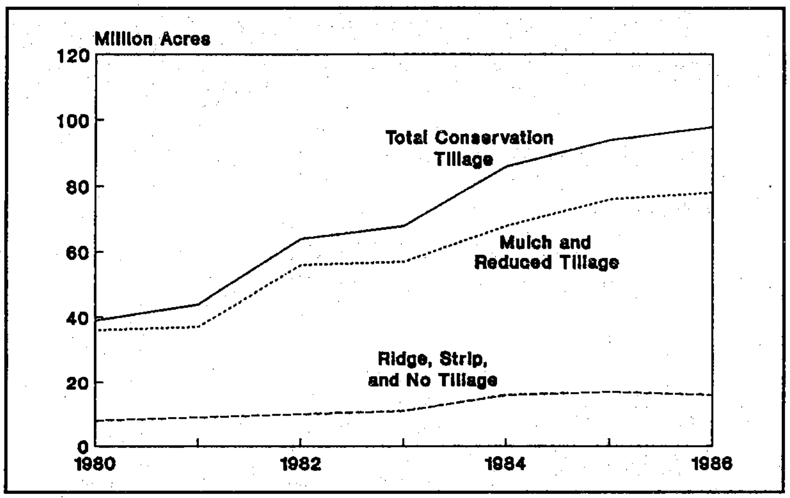

Figure 2. National Use of Conservation Tillage.
Source: USDA.

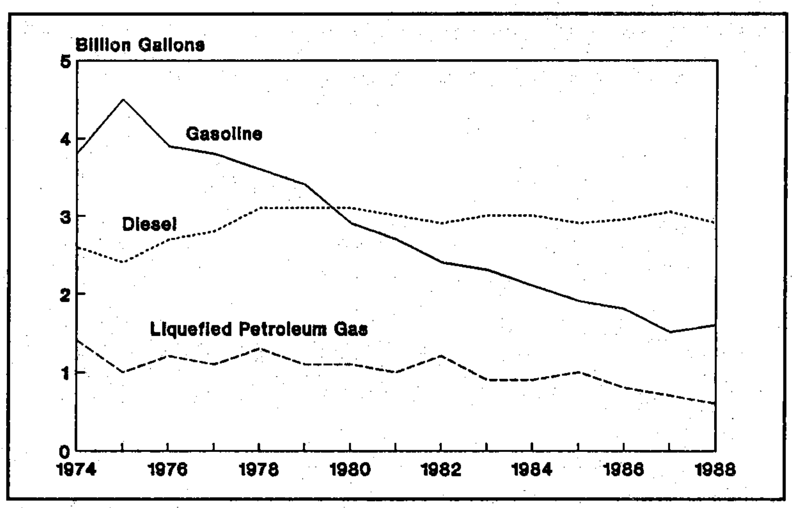

Figure 3. National Farm Use of Fuel.
Source: USDA.

To reduce costs and groundwater contamination, farmers have become more conscious of proper fertilizer application. Phosphate, potash, and nitrogen use was well below early 1980 levels in 1989 (Figure 4). Although overall nitrogen use was nearly the same in 1989 as in 1977, crop output was higher in 1989. Compared with U.S. farmers, those of the European Community and Japan typically apply 2-4 times as much fertilizer per acre.

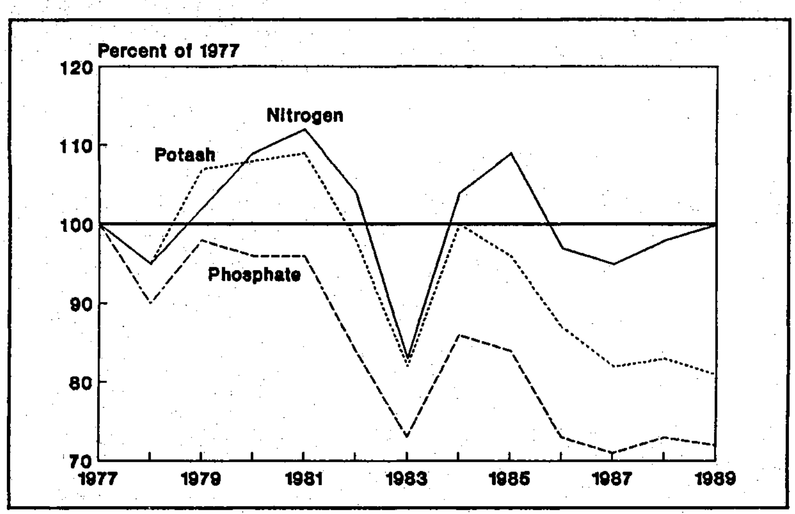

Figure 4. National Farm Use of Fertilizer.
Source: USDA.

Farmers substantially expanded herbicide use from 1966 to 1982, then began a modest decline (Figure 5) partly because of less land in crops as a result of government acreage control programs. Insecticide use fell considerably from the mid-1970s to 1982 and, along with fungicides, remained somewhat stable thereafter. As with other purchased inputs that influence the environment, the decline in use per acre demonstrates trends consistent with low-chemical agriculture which in turn is a component of ESA.[3]

Farmers will scrutinize LISA, SA, and AA just as they have scrutinized previous movements such as conservation tillage and IPM. Most farmers approach sustainable agriculture with pragmatic attitudes. Farmers will pick and choose the best practices and reject the rest. Defining sustainable agriculture narrowly as farming with *some* component of Figure 1, nearly all farmers follow sustainable agriculture! Defining sustainable agriculture more stringently as uniting *all* components (conservation tillage, IPM or ICM, legume-crop rotations, and crop-livestock systems) in an integrated system on each farm, then relatively few farmers now or in the future will practice sustainable agriculture.

[3]Alternative agriculture advocates contend that farmers use chemical fertilizers and pesticides in excess of the economic optimum, and could cut back to increase profits. While that conclusion is correct for some farmers, the reverse is probably true for many more farmers. Economists find that chemical taxes must be quite high to warrant cutbacks, implying that chemical use is highly profitable. One goal of ESA is to develop profitable alternatives to synthetic chemicals.

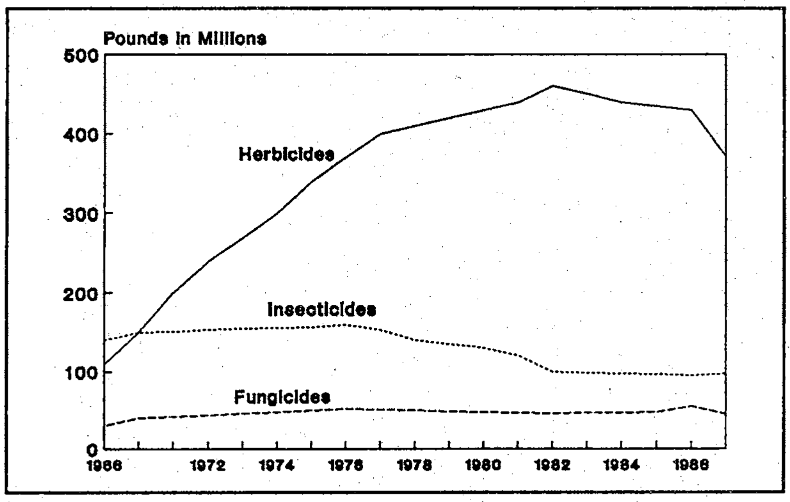

Figure 5. National Farm Use of Herbicide, Insecticide, and Fungicide.
Source: USDA.

Farmers adopt systems that meet their needs. Legume rotations for livestock or green manure do not work very well for producers of perennial crops. Many cotton, sugar, tobacco, and rice farms do not lend themselves to crop-livestock systems. The system preferred by many farmers is off-farm employment combined with cash crops that minimize labor requirements. The majority of operators will not include crop-livestock systems. Most farmers are good stewards of the land and will chose the system that preserves the soil and protects the environment -- *providing it does not sacrifice sizable profit or place undue demands on labor, management, and preferred lifestyle.*

In short, an environmentally sound agriculture properly addresses issues of soil and water conservation and prudent fertilizer and pesticide use. It addresses problems of soil erosion, groundwater contamination, and chemical residues in food supplies in part by bringing private costs in line with social costs at the margin so that food system participants have incentives to act in the public interest.

A Critique of Alternative Agriculture

The public debate over AA has become polarized and heated (see CAST, 1990). Conventional agriculture (CA) groups attack environmentalists for "economic terrorism" which cost the apple industry millions of dollars despite reassurances to the public by the Environmental Protection Agency, Food and Drug Administration, and U.S. Department of Agriculture that scientific tests gave no evidence of Alar posing a significant risk to human health. The Big Green initiative in California ignited similar fears from CA groups and was defeated by a 2:1 margin (see Doering). Many agriculturalists fear that AA alarmists will stampede the political process into costly, capricious, irrational, and arbitrary environmental policies that will erode the livelihood of producers and food abundance to consumers without achieving environmental goals. Fruit and vegetable production driven overseas by arbitrary domestic environmental legislation will be less safe when imported for U.S. consumers. The specter of Hollywood stars setting environmental policies horrifies scientists and thoughtful laypersons alike. Environmentalists have evangelized with such high moral zeal that the public, including school children, often are being propagandized rather than educated.

On the other hand, LISA advocates contend that conventional agriculture (which includes the agricultural establishment: farmers, the agribusiness sector, and government agencies) is complacent if not downright careless about the threat to food safety and human life posed by modern technology, especially synthetic chemicals. LISA advocates decry wanton exploitation of natural resources to gratify whims of a materialistic society. They contend that drastic measures such as banning many chemicals and carefully regulated use of others are essential for a safe environment and sustainable future of the planet. LISA advocates tend toward a negative time discount rate, prefering consumption in the future to consumption today. They call for mandatory regulation of activity, including that of farmers, to serve environmental ends. LISA advocates tend to be pessimistic regarding technology and substitutes for existing nonrenewable resources. In contrast, conventional agriculturalists are more optimistic that the limits of growth can be overcome by intelligent action and technology so that standards of living can improve indefinitely.

Environmentalists frequently are *subjectivists* who believe in the primacy of feelings and perceptions and are skeptical of data, science, the scientific method, and the establishment in general. (Their finest hour was in opposition to the Vietnam War.) Subjectivists tend not to trust government, but paradoxically call for a heavy role for government to achieve environmental ends. Subjectivists frequently place environmental above human needs (Earth First!); objectivists view nature as a resource to use in improving well-being of society.

The conflict between conventional and alternative agriculture advocates stems partly from misunderstanding. CA widely confuses AA with organic farming. AA is not organic farming, although some adherents advocate it and a few practice it. AA widely and incorrectly perceives that conventional agriculture is a tool of chemical companies and is unconcerned about the environment or future generations of people.

The political-economic system lends itself to such polarization and antagonisms. Because the impersonal and efficient market price system alone will not protect the environment, the public must turn to the political process. Formulating an agenda and regulations through the political process in a field short of facts and long on special-interest groups generates adversary relationships, distortion of what little is known, overblown rhetoric, and appeals to emotions. That is hardly the atmosphere to make sound public policy decisions affecting millions of producers and consumers. Unlike a well functioning market, no self-adjusting impersonal mechanism comparable to price guides the political process to ensure optimal allocation of chemicals. Overuse or underuse will be the rule, not the exception!

Economists favor greater reliance on markets to avoid mandatory environmental controls. The procedure is to tax fertilizers, pesticides, and soil erosion so that costs to the firm reflect costs to society. Economists call this *internalizing* to the accounts of firms the *externalities* that ordinary afflict outsiders but do not enter firm accounts -- unless a tax or subsidy is imposed. Producers then face continuing incentives to make private decisions in the public interest without regulatory harassment by outsiders. That system works because, on the whole, farmers respond to incentives. Such an approach increases *real* national output. On the other hand, reliance by environmentalists on exhortation and patriotic appeals soon brings attention-span fatigue. Even if converted, producers and consumers eventually revert to acting in their self-interest in the absence of market incentives.

A second major source of polarization was publication of the controversial report *Alternative Agriculture* by the Committee on the Role of Alternative Farming Methods under auspices of the National Research Council (NRC) of the National Academy of Sciences. Numerous aspects of the report have been criticized (see CAST, 1990). The major shortcoming of the report was to leave the impression that low-input sustainable agriculture is a proven system capable of supplying adequate safe food supplies at less cost. The committee relied on numerous uncontrolled case studies of unknown scientific merit and generalizability. Press interpretation is illustrated by the following examples:

> The Council concluded that alternative methods can reduce such effects [environmental damage from conventional farming methods] without adversely affecting food supply. [Brisbane, *Washington Post*, p. A10]

A leading New Jersey newspaper, the *Newark Star Ledger* (see Marten, p. 112) reported that

> The National Academy of Sciences has conducted an extensive survey on the value of pesticides. Its findings: Farmers who apply little or no chemicals to crops are usually as productive as those who use pesticides and synthetic fertilizers.

Overestimating the promise of alternative agriculture can cause mischief, not the least of which is complacency toward investing in science and technology to raise agricultural productivity with technologically improved inputs. The National Resource Council Committee recommended a tenfold increase in federal funds for LISA to $40 million per year but even this amount falls far short of needs to increase agricultural productivity and food and water safety through science.

Some alternative agriculture activists embrace a larger agenda including (1) sustainable agriculture, (2) a shift from large to small family farms, (3) national, regional, and even individual farm self sufficiency and an end to export cropping, (4) animal rights, (5) a food system run "for people and not for profit," and (6) assured economic viability of farms and rural communities. A few extremists in the environmental movement call for mandated organic farming, an end to use of non-renewable energy such as petroleum, a return to non-intervention in nature, and to rejection of modern science and technology.

Faeth (p. 2) contends that

> the concept of sustainability extends beyond the farm community, or region, and can be applied to: the field system (agronomic); or landscape system (ecological); and the regional, national, or international system (macroeconomic).

The messianic reach of sustainable agriculture is evident in the literature of the movement. For example, Enshayan (p. 10) states that

> A sustainable agriculture is rooted in a sustainable world, a world free of injustice, oppression, and violence towards the earth and the people. The land grant institutions must reclaim the goal of creating that world.

LISA systems in the United States attempt the commendable goal of reducing synthetic chemical input use. But to maintain output, difficult tradeoffs are apparent:

1. Reducing chemical use often requires more labor, management, and total inputs per unit of output than do conventional systems. Cash cost per unit of output may be lower but total cost and hence food prices are higher.
2. Reduced pesticide use often requires more mechanical means to control weeds. This means more fossil fuel consumption and more soil erosion.
3. Conservation tillage often requires more synthetic herbicides.
4. Less synthetic fertilizer requires more green manure, sludge from urban sewage, or livestock manure. Manure may pollute more than synthetic fertilizer because manure cannot be banded and targeted. Sludge is frequently contaminated with heavy metals. The metals working through the food chain can reach concentrations toxic to human beings.
5. Yields are reduced or land is devoted to green manure so that, to meet food needs, more area must be cropped with attendant problems of soil erosion.
6. Banning or highly restricting use of synthetic pesticides can jeopardize IPM which depends on effective pesticides to stop damage once pests reach an economic threshold level.
7. Widespread movement of farmers to crop-livestock systems utilizing forage legumes in rotations, and returning nutrients to the field in manure could bring excessive meat and livestock output.
8. If farmers purchase manure from neighbors, costs are high and each farm would not be sustainable in nutrients. If farmers produce green manure from forage legumes without livestock, costs of crop production could rise. Green manure is expensive fertilizer measured by lost alternative uses of land. Whole-farm productivity could decline even if commercial crop yields are maintained because some cropland must be in noncommercial legumes.
9. It is economically impractical to disperse manure from large, specialized livestock operations to crop farms throughout the country. Such livestock farms are too few and far between to

supply nutrients without massive transport costs. Heavy taxation of point-source pollution or other policy measures making large feedlots uneconomic could drive livestock production back to family farms but could entail large costs to consumers and massive adjustment problems for producers.

10. Bovine and porcine growth hormones reduce natural and manmade resources required to produce a given food output but are considered unsafe by some people. Milk produced using growth hormones has been rejected by some states and supermarkets despite scientific assurances of food safety. In a related issue the European Community banned American beef imports in 1989 because slaughter cattle were fattened while receiving growth-promoting hormonal implants, usually containing estrogen.[4]

11. Banning chemicals and hence dropping production in California, for example, would raise American consumption of fruits and vegetables imported from Mexico produced by more dangerous chemicals than those banned in California.

12. Crops produced from varieties bred to resist pests with natural pesticides may be more carcinogenic than current varieties produced with synthetic chemicals.

Because labor and management requirements expand under LISA, it is not necessarily a low aggregate input system. Furthermore, if the producer takes the extreme position of bringing no chemicals (including manure and petroleum products) from off the farm, LISA is not sustainable. All systems experience entrophy and leak nutrients which must be restored to maintain productivity. Phosphate and potash and often nitrogen and trace elements must be brought in from outside to maintain the system. Or science and technology also

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[4]In most cases, hormones are withdrawn well before slaughter as required by law so that residues do not remain in beef. In some cases, hormones are not removed in time so residues remain in beef. However, because estrogen is a naturally occurring hormone neither toxic nor carcinogenic in minute residual levels found in beef, the issue is more one of politics and trade protectionism rather than of environment or food safety.

from outside the system must be introduced to develop cultivars requiring less of the lost inputs to supply food and fiber needs.[5]

Despite weaknesses of today's modern system of farm production, it has sustained productivity advances averaging nearly 2 percent per year since the 1930s. Many scientists are confident the emerging biotechnologies and other scientific advances can advance conventional resource productivity indefinitely. Knowledge through science makes the system dynamic and growing even in the very long run. Only a system that harnesses the contributions of science, industry, and producers is sustainable.

Sustainability is not enough, however. The objective instead must be wise use of *all* resources -- natural and man-made -- for a *dynamic, growing* food and fiber system in the long run. Antagonism between agricultural scientists and low-chemical agriculture advocates serves the interests of neither group, nor of the nation, nor of a growing food and fiber system. Reliance on a science and technology fix alone or on natural systems alone is inadequate.

A case can be made that land grant universities have not adequately emphasized whole-farm *systems* research. Universities are not especially good at such research requiring isolation of causal effects when many variables are varying at once. Universities are best at controlled experiments where individual causes and effects can be identified and measured. Although the major contribution of public agricultural research institutions has been and will continue to be development of components of sustainable agriculture systems shown in Figure 1, they can perform more research on whole farm systems. However, the approach is best suited for farmers themselves with technical assistance from scientists so that objective results can be generalized and disseminated by the Cooperative Extension Service and other outlets. To that end, the omnibus farm bill of 1990 showed wisdom not only by raising low-chemical systems (LISA) annual research funding from $4 million up to $80

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[5] I have spent much time in sub-Saharan Africa where the low-input agriculture system is standard. The shifting "slash and burn" rotation is widely practiced to maintain soil fertility without outside inputs. Land is cropped and then allowed to return to bush or forest for several years. This system provides very low productivity and living standards; consequently, disease, poverty, famine, malnutrition, and short life spans are common.

For thousands of years the shifting rotation system was a low-input sustainable agriculture. It no longer is sustainable because conditions have changed. Food demands of a growing population are forcing shorter fallow periods in Africa. Millions will suffer unless modern science, technology, and human and material capital formation alter the low-input system.

million but also by raising annual funding by up to $500 million for competitive-grant-allocated basic and applied biological and other research. Actual appropriations are likely to fall far short of these authorizations, however.

In summary, sustainable agriculture is practical and original. But what is practical (the individual components in Figure 1) is not original, and what is original (the full synergism) is not yet generally practical. Few farmers indeed are likely to adopt the entire sustainable agriculture package. An agricultural system must be indefinitely expandable to meet long-term food and fiber needs, and that is possible only by combining compotent farm husbandry with a strong scientific program to raise productivity of natural and other conventional resources. An environmentally sound agriculture (ESA) is a worthy objective widely supported by Americans but the economics and policies for ESA remain in a formative stage.

Urgency of Environmental Problems

Before examining the economics of low-chemical agriculture, it is useful to gain perspective by appraising the urgency of environmental problems. Recent data leave no doubt that environmental problems are real but are often overstated.

Drinking Water Safety

In the first results released from an extensive five-year study entailing 1,347 wells in 50 states, the Environmental Protection Agency in late 1990 reported finding nitrate in more than half the water wells sampled. (EPA, p. 1). Nitrate, which could come from decomposed organic matter or commercial fertilizer, was found in 52 percent of urban (and suburban) wells and 57 percent of rural wells. However, only 1.2 percent of the urban and 2.4 percent of the rural wells contained concentrations above levels considered safe by the EPA. Excessive exposure to nitrate can lead to the so-called "blue baby syndrome" in infants, a blood disorder in which the blood's ability to carry oxygen is reduced.

Surprisingly, the proportion of urban wells contaminated with at least one pesticide (10 percent) was greater than the proportion of rural wells containing at least one pesticide (4 percent). However, less than 1 percent of either the rural or urban wells had pesticide residues above standards established by EPA. Given the margin for error built into chemical standards, the survey results do not demonstrate any immediate widespread health problem.

It is notable that the most frequently found pesticide was dacthal, a broadleaf week killer used primarily on urban lawns. In all cases, concentrations were too low to be considered harmful.

The proportions of well-water contamination from natural versus synthetic sources is unknown. Also unknown is how levels of contamination have changed over time.

Chemicals in Food

Virtually all plants produce natural toxins to protect themselves from predators such as insects and fungi. Thousands of these natural toxins have been discovered and many are carcinogenic. Ames and Gold (1989, p. 756), scientists at the University of California-Berkeley, state that "It is probable that almost every plant product in the supermarket contains natural carcinogens."

Current testing procedures exaggerate human cancer risks from chemicals. Chronic dosing in tests at near-lethal maximum tolerable dose (MTD) levels chronically wounds rodents' cells. This results in cancer, not because the chemicals are carcinogens within any meaningful range of actual dosage by humans, but because nearly anything that causes repeated cell destruction and regrowth eventually produces cancer. About half of all chemicals, *natural* or *synthetic*, are carcinogenic in rodents when tested at MTD levels.

Three classes of chemicals are apparent: (1) those which do not cause cancer under any conditions; (2) those which result in cancer at low, medium, or high levels; and (3) those causing cancer only at near MTD solely because they wound cells. Category (2) can be banned or tightly controlled whereas (3) may need controls only in cases where people are exposed to very high dosage. Under category (3), cancer risk is *not* a linear function of dose -- risk is zero at low or medium doses. The Delaney Clause forbids, in processed foods, synthetic chemicals which have been found to be carcinogenic in rodents, even if they are category (3) and hence are only remotely carcinogenic because they wound cells in massive laboratory doses never found among humans.

Daily intake of natural pesticides is about 1500 mg per person or 15,000 times the daily average intake of .1 mg per day of synthetic pesticide residues. Ames and Gold (1990, p. 970) estimate that 99.99 percent of pesticides in human diets are natural. They (1990, p. 971) note, for example, that coffee contains 826 volatile chemicals. Of the mere 21 which have been tested, 16 are rodent carcinogens. A cup of coffee contains at least 10 mg of rodent carcinogens. Thus a person who drinks three cups of coffee daily receives as much natural carcinogens from coffee in one day as he/she receives from synthetic chemical residues in one year.

Alar caused major public controversy resulting in economic damage to the apple industry and a ban on the use of the chemical used to uniformly ripen apples. Ames and Gold (1989) estimate that the lifetime chances of cancer are over 10 times greater from daily consumption of a mushroom or a peanut butter sandwich (which contains carcinogenic aflatoxin) as from daily consumption of a 6 ounce glass of apple juice containing the trace amounts of Alar detected in 1989.

If the Delaney Amendment which outlaws any food additives capable of producing cancer were applied to any food containing naturally occurring carcinogens, virtually all foods would be banned! Even the scientists who have found naturally occurring carcinogens in naturally (including organically) produced apples, bananas, brussels sprouts, cabbage, cantaloupe, carrots, cauliflower, celery, radishes, raspberries, turnips, spices, and many other foods continue to consume the foods because the risks are too low to be of concern. On the other hand, anticarcinogenic vitamins and antioxidants in fruits and vegetables reduce cancer rates. Evolution has given humans layers of defenses against synthetic and natural toxins at low doses. The adage "the dose makes the poison" remains useful. But tests for carcinogens clearly need improvement.

Organically grown foods have no greater nutritional value than conventionally produced foods but risks of toxins and carcinogens may be greater for several reasons. First, the choice of varieties and nature's response to pests may cause higher levels of natural toxins and carcinogens in organically grown foods. Second, organically grown foods often do not benefit from the cleaning, cooking, or other processing that reduces hazards in conventional foods. Rotting, insect infestation, and other problems of organic foods increase risk of food poisoning. Finally, additives such as iodine in salt and vitamins and minerals in processed foods offer nutritional advantages.

A large number of foods are classified in the "generally recognized as safe" (GRAS) category by federal agencies, and have not been tested for potential natural toxins and carcinogens. The foods are in the GRAS category because, though widely consumed, they do not have a history of causing difficulties. A useful working assumption is that they are safe, but complacency is not in order. To the extent resources allow, these too should be tested. Results would allow the public to make the decision whether hazards posed by consumption outweigh the nutritional and taste benefits Americans so richly enjoy from food.[6]

The market gives consumers the opportunity to chose which foods to purchase subject to price. Many states have programs to certify foods as organically produced but the nationwide labeling and standards provided in the 1990 farm bill are welcomed. Because production and marketing costs are usually higher for organic foods, retail prices are higher than for conventional foods. Sometimes tight supplies also cause high prices. Consumers free to chose organic foods can vote for more by paying higher prices which in turn are passed to producers, encouraging greater supply. That's the way a market should work. In contrast, a government regulated market might force everyone to pay for organic foods although many consumers find no more value in them than in conventional foods.

Some consumers are willing to pay more for food not just because it has no chemical residues but because it was produced under conditions reducing soil erosion and groundwater contamination. Hence at least two certified labels are needed: (1) organically (synthetic chemical free) grown, and (2) environmentally sound. The latter would be produced under practices in Figure 1 -- it would be safe but some benign chemicals could be used in production.

Gross claims are easy to make, easily mislead, and difficult to refute in an area where all too little factual information is available.[7] For example, Ayer (p. 73) states that "Common pesticides on American foods

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[6]The argument that natural carcinogens are safer than synthetic ones cannot stand scrutiny. A substantial number of foods consumed regularly are relative newcomers to diets. Specific human defense mechanisms have had no more chance to evolve specific defenses against the natural than to these synthetic carcinogens. It appears that body defense mechanisms are *general* to all natural and synthetic chemicals.

[7]The public's willingness to accept far greater risks in say automobile driving than in food safety appears to be tied to level of knowledge, control, and trust. Even when science indicates no basis for concern, people often react negatively because they do not understand or trust scientific procedures and lack individual control over unknown amounts of residues in food and water. This does not explain the public's willingness to tolerate very high levels of natural carcinogens in food, however. The latter is explained by greater acceptance of *old* risk than of *new* risk, a dimension of trust.

are estimated to cause 20,000 incidents of cancer each year." No source was cited by Ayer but it apparently was a now discredited study conducted by the National Research Council in 1987. One of the architects of that study, Arthur Lipton, more recently estimates that current exposures are associated with risks (not deaths) of "under 400" persons, and Robert Scheuplein, head of food technology for the Food and Drug Administration, says cancer risks from all pesticides are fewer than 50 per year and "very probably zero" (see Brookes, p. 9A).

Although the American food supply is free of all but negligible chemical risk, food entails difficult tradeoffs between safety, cost, variety, palatability, and protection of resources. Absolute safety or absolute protection of soil and water is neither technically nor economically feasible.

The above data are intended to cause neither panic nor complacency among consumers, but unsafe food kills. In the United States, food poisoning from "natural" listeria, salmonellae, and campylobacter account for some 33 million illnesses and 9,000 deaths in human beings each year (Young). These deaths far outnumber those from synthetic chemical contamination of food. Of note here is the potential link between organic farming and food poisoning. For example, a 1981 outbreak of listeria in Nova Scotia killing nearly half of the afflicted 51 persons was traced to cole slaw made with cabbage grown on a field fertilized with sheep manure -- the alleged source (Carroll, p. 3).

Some deaths may result from bacteria which have developed resistance to antibiotics administered to animals. Such deaths could be charged to environmental degradation to the extent resistance in pathogens was developed by unnecessary subtherapeutic application of antibiotics. Fortunately, subtherapeutic use of antibiotics is down.

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Most of the annual 9,000 deaths from food poisoning could be prevented with proper use of chemical preservatives, cooking, processing, and storage. Deaths from food poisoning might be higher in the absence of synthetic chemicals which suppress production of natural pathogens.

Lack of care in applying chemicals may pose more health hazards than chemical residues in food. Ayer reported (p. 73) that "Kansas farmers who were exposed to herbicides for more than 20 days per year were found to have six times the risk of developing non-Hodgkin's lymphoma as nonfarmers." Training and regulation of applicators is critical.

Soil Erosion

Soil erosion continues to be the number one environmental problem of agriculture although many today would rank chemical residues in soil, water, and food to be more important. An American Agricultural Economics Association Policy Task Force (AAEA) in 1986 estimated the discounted value of 100 years of soil erosion to be no more than $17 billion -- about one hundred times lower than the earlier estimate by Troeh *et al.* Several subsequent studies by Alt and Putnam, the U.S. Department of Agriculture, soil scientists at the University of Minnesota, and by Crosson of Resources for the Future reach conclusions consistent with the AAEA study. The preponderance of studies indicate that soil erosion at current levels would reduce soil productivity by about 5 percent in a century (see CAST, 1988, pp. 23, 24 for summary of these studies). This reduction in productivity from soil erosion can be offset at a cost by measures to raise farming productivity.[8]

Farmers aware of current and future lost productivity on their operations might be expected to use soil conserving practices to raise current profits and to maintain land values. Off-site damages do not enter private accounts of firms, however. If such costs are large, reliance on the market alone will not optimize conservation even if, as evidence indicates, farmers do a pretty good job of equating private costs with private benefits at the margin. The Conservation Foundation has estimated that off-site damage of soil erosion from farm and nonfarm sources totals $3.2 to $13 billion per year, and cropland alone may contribute $2.2 billion annually to this off-site damage (Clark *et al.*). In a slightly more recent study, Ribaudo estimated off-farm costs from sediment, nutrients, and chemicals in water of $7.1 billion compared to the point estimate of $6.1 billion by Clark *et al.*

In short, environmental problems of agriculture are very real and will not be resolved by the market alone. At issue is the role of alternative agriculture and government policy in the process of protecting the environment -- an issue to be discussed in the final section after discussion of economic studies in the following section.

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[8]Troeh *et al.* in 1980 estimated that soil nutrients with a value of $18 billion are lost annually from agriculture by soil erosion. Fertilizer outlays totaled only $7.5 billion in 1989, hence the loss appears to be overestimated. Many nutrients would be lost each year even in the absence of soil erosion due to entropy and other causes. The reduced concern over soil erosion inspired in part by the above studies is apparent in the 1990 farm bill which gave much more emphasis to water than to soil protection.

Economic Evaluation of Farming Systems

Economic analysis of alternative agriculture has relied on two general types of studies. One is case studies which illustrate the promise of alternative systems in isolated cases with operators holding the proper "philosophic" orientation. Such studies cannot be generalized. After learning what we can from case studies, we turn to more scientific and comprehensive studies which unfortunately fail to capture the synergistic benefits of the systems approach in alternative agriculture.

Farm-Level Studies

Before turning to studies examining the economy-wide impacts of sustainable agricultural components, several farm management type studies are reviewed which do not attempt to account for national impacts.

1. Case studies. Because data from scientifically valid large studies are not available, we begin by summarizing case studies from the National Research Council's Committee on The Role of Alternative Farming Methods (NRC, pp. 253-417). Case studies represent exemplary rather than typical applications, but provide insights into the scope and promise of alternative agriculture.

Results are summarized in Table 1. Selected observations and issues regarding the case studies are presented below.

a. Out of 14 farms, the Spray Brothers farm in Ohio is the most outstanding example of a successful alternative agriculture system encompassing low chemical use, rotations, crop-livestock systems, and/or conservation tillage. The operation is economically and environmentally viable, and appears to be sustainable. Frequent cultivation of row crops, essential to control weeds, is an environmental hazard even on this farm, however. Issues of economic sustainability are raised by the fact that significant expansion of organic production in the nation could remove the premium prices received by the Spray Brothers for organic foods. And few farm operators possess the required managerial capabilities.

The BreDahl farm had many elements of alternative agriculture but economic returns appeared to be a problem. The Thompson farm also in Iowa had many successful practices such as ridge tillage but use of sludge fertilizer raises questions of sustainability, generalizability, and heavy-metal toxicity.

b. The examples clearly illustrate that alternative agriculture is not necessarily small farms or organic farming. The gap between conventional and alternative agriculture fades into differences of degree rather than kind. Most of the practices used on the farms such as IPM and ridge till are conventional practices. The agricultural extension service and land grant universities recommend such practices where resources are suited for their use.

c. All farms lack essential data on:

* Aggregate output. Yield of (say) grain may be maintained with LISA farming by producing legumes for green manure. However, land devoted to green manure detracts from whole-farm output and, if practiced nationally, could sharply reduce food output and raise food prices.

* Efficiency. Aggregate value of output and full economic cost of inputs data were unavailable for the farms. It is possible that higher labor and management costs make these *high input unsustainable agriculture* systems. A farm economically not viable and thus unable to survive will not be environmentally or socially viable. Most farms had been in existence for some years. Some may be living off equity acquired while farming more conventionally.

* Groundwater contamination. We do not know the impact of these farms on water quality. Green or livestock manure and other natural fertilizers can pollute groundwater as fully as can synthetic fertilizers and pesticides.

Table 1. Case Studies of Alternative Agriculture Applications.

Case Study	Economic	Environment	Sustainability
1. **Spray Brothers.** Mixed crop-livestock Ohio 720 acres	Yes, with excellent management and premium prices.	Organic but cultivate frequently.	Unknown. Unusually high level of management not available on most farms. Premium prices for organic food output could be jeopardized by expansion of supplies. Few farm operators can match this management.
Comment: An excellent example worthy of study by other farmers and by scientists.			
2. **BreDahl Farm.** Mixed crop-livestock Southwest Iowa 160 acres	Net returns inadequate some years. Essential to have "a small enough operation to manage properly."	Commercial fertilizers and 2,4-D herbicide.	Unknown but probably troubled by inadequate long-term economic returns.
3. **Sabot Hill Farm.** Mixed crop-livestock Virginia 3,000 acres (half forest)	Costs and returns data unavailable.	Commercial fertilizers and herbicides.	Harvest Johnsongrass, a questionable practice for most farmers.
4. **Kutzdown Farm.** Mixed crop-livestock Pennsylvania 305 acres	Unknown, but labor requirements 10-30% above conventional farms. Nonlabor costs low.	Starter fertilizer, cultivate 2-3 times, herbicides on non-Rodale land, antibiotics.	Chicken manure purchases.
Comment: Yields "disastrous for several years after introduction of organic farming." Kutzdown Farm 3-10% "more profitable" than conventional farm, both holding erosion to 3-5 tons per acre, but labor, management, and full machinery costs not included.			

Table 1 cont.

Case Study	Economic	Environment	Sustainability
5. Thompson Farm. Mixed crop-livestock Iowa 300 acres	Lower than conventional farming costs including labor.	Commercial fertilizer, herbicides and antibiotics used selectively. Ridge till. Cultivate 3 times. Municipal sludge could pose heavy metal problem.	Protein supplement. Sludge and manure imports not a sustainable system if practiced by all farms.
6. Farrari Farm. Fruits, walnuts, & vegetables California 223 acres	Costs, returns, and profitability data unavailable.	Part organic, part IPM. Commercial fertilizer used. Bordeaux solution (containing copper sulfate) used on organic portion. "Natural" pesticides used on organic portion.	Composted manure purchased. Water table for irrigation declining. Price premium for organic crops.
7. Four fresh-market vegetable farms. Florida 350-9,640 acres	Overall performance data unavailable, but "all farms appear to be financially viable."	All farms use IPM, advised by same service firm. Use pesticides and commercial fertilizers. Groundwater pollution from fertilizers and pesticides may be a problem.	IPM attempts to use proven and new techniques including biological controls which are sustainable. Mostly just conventional operations with good management.
Comment: IPM is a conventional technique used by producers who wish to increase profit.			
8. Pavich and Sons. Grapes Arizona & Calif. 1,432 acres	Apparently profitable operation. Premium price received for organically grown grapes.	No herbicides, but use IPM and insecticides, fungicides, and fumigants. Some grapes organically grown. Groundwater pollution may be a problem; no data given.	Purchase composted steer manure and well and river water irrigation. Irrigation subsidized.

Table 1 cont.

Case Study	Economic	Environment	Sustainability
9. Kitamura Farm. Nuts and vegetables California 305 acres	Apparently profitable, but data lacking.	IPM; use herbicides, pesticides, and commercial fertilizers.	No data, probably better than average. Groundwater contamination from fertilizers could be a problem.
10. Coleman Farm. Livestock-range Colorado 26,000 acres	Net returns to ranching less than hired labor wage. Finishing, packing, and sale of beef profitable because of 25% premium price.	No fertilizer or lime used in ranching. Natural beef markets from portion of cattle receiving no antibiotics or growth hormones.	If supply of natural beef expanded, price premium would erode. Fertility of irrigated hayland may drop without fertilizer application. Animals requiring medication sold in conventional markets. Purchased feed with minimal assurance of no chemical use.
11. Lundberg Family Farms. Rice California 3,100 acres	Uncompetitive. Organic rice receives 50% premium price but yields 40% lower. Net return 30% lower for organic under good conditions.	Use largely conventional farming methods, but experiment with 100 acres of organic rice without pesticides or synthetic fertilizers.	Premium price for organic produce would drop if supply expanded markedly.

Source: NRC.

* Environmental tradeoffs. Less herbicide use often requires more mechanical control of weeds. What is the fuel-herbicide tradeoff? Lower yields with low-chemical systems may require more cropland to meet the nation's food needs. More cultivated cropland exposed to the elements means more soil erosion.

d. The case studies repeatedly showed the importance of public agricultural research and extension. Many farms depended on technologies developed by agricultural experiment stations. Far from showing alienation of alternative agriculture from extension services and land grant universities, these studies reveal that sustainable agriculture depends on past and future science and technology.

In summary, the studies provide evidence that good management along with appropriate technology obtained from other farmers, agribusinesses, and scientific establishments can reduce chemical use and environmental degradation in producing crops and livestock. But the studies provide a limited understanding of the economic and environmental viability of alternative agricultural systems extended to the nation.

2. Reduced tillage in Ohio. We now turn from case studies to farm management data for reduced tillage practices such as no till, ridge till, and minimum till to cut soil erosion, chemical use, and overall costs. Budgets in Table 2 show annual costs per acre for a hypothetical 1,500 acre cornbelt family farm in Ohio under four types of tillage systems.

Yields and gross returns are assumed to be the same over all tillage systems. In reality, however, yields differ because some systems are better suited to some resource situations. For example, conventional till generally requires less management skill than ridge till, although the latter may have soil erosion rates only one-fourth those of conventional till or minimum tillage. Herbicide costs (other pesticide use is nominal) are higher with no-till than with conventional till but are lowest with ridge till. Commercial fertilizer use did not differ markedly among systems. No-till and ridge till are not suited to some soils. Some perennial weeds are difficult to control with non-conventional tillage.

The important point of Table 2 is that environmentally sound practices can also be economically sound. Based on the data, we would expect a move away from conventional tillage to other tillage forms. That is precisely what we observed in Figure 2. But again it is noted that alternative systems are not suited for all situations.

Table 2. Summary of Machinery, Labor, Herbicide, and Other Costs for Tillage and Planting on 1500 Acres in Ohio, 1990.

	No Till[a]	Ridge Till[b]	Minimum Till[c]	Conventional Till[d]
Total Machinery Investment/A	$57.00	$85.00	$114.00	$150.00
Fixed Machinery Costs/A/Yr	6.08	8.96	11.97	15.65
Variable Machinery and Labor Costs/A/Yr	4.27	10.84	10.07	14.47
Total Machinery and Labor Costs/A/Yr	10.35	19.80	22.04	30.12
Variable Herbicide Costs/A/Yr	22.80	5.73	17.20	17.20
Total Machinery, Labor, and Herbicide Costs/A/Yr	33.15	25.53	39.24	47.32

Source: Lines, Reeder, and Acker.

[a]Practices/Implements	Tractor Hours
Plant 600 A corn @ 5.09 A/Hr with 120 HP tractor and 8-30″ minimum-till planter	118
Drill 900 A soybeans & wheat @ 5.57 A/Hr with 60 HP tractor and 14′ drill	162
Total tractor hours	280

[b]Practices/Implements	Tractor Hours
Plant 1200 A corn & soybeans @ 5.09 A/Hr with 120 HP tractor and 8-30″ ridge till planter	236
Drill 300 A wheat @ 5.57 A/Hr with 120 HP tractor and 14′ drill	54
Cultivate 1200 A corn & soybeans twice @ 7.76 A/Hr with two 120 HP tractors and 8-30″ ridge cultivators	309
Total tractor hours	599

[c]Practices/Implements	Tractor Hours
Chisel 900 A corn & wheat stubble @ 8.73 A/Hr with 225 HP tractor and 20′ chisel plow, Fall	103
Field cultivate 1500 A @ 13.58 A/Hr with 225 HP tractor and 28′ field cultivator, Spring	110
Plant 600 A corn @ 5.09 A/Hr with 120 HP tractor and 8-30″ minimum till planter	118
Drill 900 A soybeans & wheat @ 11.15 A/Hr with 120 HP tractor and 28′ drill	81
Cultivate 300 A corn once @ 7.76 A/Hr with 120 HP tractor and 8-30″ cultivator	39
Total tractor hours	451

[d]Practices/Implements	Tractor Hours
Plow 900 A corn & wheat stubble @ 5.89 A/Hr with 275 HP tractor and 9-18″ plow, Fall	153
Chisel 600 A soybean stubble @ 8.73 A/Hr with 160 HP tractor and 20′ chisel, Fall	69
Seedbed preparation 1200 A corn & soybeans (Spring) and 300 A wheat (Fall) @ 17.94 A/Hr with 275 HP tractor and 37′ field cultivator	84
Plant 600 A corn @ 6.55 A/Hr with 120 HP tractor and 8-30″ conventional planter	92
Drill 900 A soybeans & wheat @ 11.15 A/Hr with 120 HP tractor and 28′ drill	81
Cultivate 600 A corn once @ 7.76 A/Hr with 120 HP tractor and 8-30″ conventional cultivator	77
Total tractor hours	556

A critical observation is that four to six money-losing transition years may be required to move from conventional to money-making synergistic alternative agriculture. Machinery power requirements are less for alternative agriculture but it costs money to trade for the proper machinery. And there's always the risk that the transition won't be successful.

3. Reduced tillage in Pennsylvania and Nebraska, including off-farm erosion costs. A study by Faeth *et al.* calculated net farm income per acre assuming a comprehensive accounting for on-farm and off-farm erosion costs and other environmental damages. The study also considered various rotations and production practices, including conservation tillage, under various public policy scenarios for resource situations in Pennsylvania and Nebraska. Results are of interest because they constitute the most complete accounting to date for full costs and returns under prices estimated to prevail in the absence of commodity programs tied to production.

Table 3. Comparison of Conventional with Reduced Tillage Organic Rotation in Pennsylvania and Nebraska.

Rotation	Soil Erosion		Off-Farm Erosion Cost		Soil Depreciation		Net Economic Value[a] after Transition Period	
	PA	NB	PA	NB	PA	NB	PA	NB
	(t/ac/yr)		($/ac/yr)		($/ac/yr)		($/ac/5 yrs)	
Corn-Beans (conventional tillage)	6.1	3.7	47	2.3	25	3.0	232	561
Corn-Beans-Corn Oats/Clover (reduced tillage) Organic treatment	3.5	2.2	27	1.5	(3.6)	(4.0)	457	445

Source: Faeth *et al.*

[a] With multilateral decoupling: Global elimination of commodity programs tied to production.

In Pennsylvania, where on-farm and off-farm environmental costs are high, the authors concluded that after a transition period resource-conserving measures cut production costs by 25 percent, reduced soil erosion by 50 percent, increased yields, and nearly doubled net economic value per acre over conventional farming (see

Table 3). In Nebraska, where on-farm and off-farm environmental costs are relatively low, alternative agriculture systems had a less decisive advantage over conventional farming. Alternatives to the conventional corn-soybeans rotations were not competitive economically (See Table 3).

The Faeth *et al.* study showed that (1) current commodity program policies give incentives for resource-degrading farming practices, (2) a transition period from conventional to more environmentally benign practices can be a difficult hurdle for farmers because of low yields and economic returns, and (3) a tax of 25 percent on synthetic chemicals is sufficient to make resource-conserving practices as profitable as conventional practices under some circumstances. Commodity program payments could be used to east the transition toward less dependence on chemicals. Although the numbers in Table 3 need to be refined, the full social cost and return accounting used by the authors is highly recommended and is consistent with the policy of full social cost pricing called for in this paper.

Non-distorting commodity programs help private firms acting in their own interest to bring desired changes in farming practices. Although many operators may not observe and hence respond to productivity loss due to soil erosion, it does enter the private accounting of firms through productivity maintenance costs (e.g., for fertilizers) and land price depreciation. Only off-farm erosion cost is an externality that does not enter the firm's profit and net worth functions. A problem in trying to internalize it with taxes is that off-site costs differ not only by individual farm but also by downstream characteristics. For example, erosion that enriches a neighbor's forestland has a quite different impact than silting of a city water reservoir. Thus the Soil Conservation Service would need to monitor watersheds and individual farms, uniquely tailoring penalties and subsidies to align private farming practices with public needs.[9] The nation is not prepared for that cost of monitoring and enforcement.

Given the wide variation in off-site erosion costs found by Hitzhusen and Kabongo, considerable effort would be required to tailor costs to each farm. Taxes of $10 per ton on erosion in excess of the soil tolerance

[9] The approach generally followed in farm policy is for the government to pay farmers for following sound environmental practices. The approach in the nonfarm sector usually is to tax or regulate. A major concern of farmers is that farm environmental policy will shift from the Soil Conservation Service and Agricultural Stabilization and Conservation Service which use the "carrot" of incentives and to the Environmental Protection Agency, the National Fish and Wildlife Service, and other federal agencies which use the "stick" of regulation or fines to force compliance.

level might appear inequitable and excessive especially to landowners who purchased land before the policy was introduced. However, the tax expense might be reduced at low cost by conservation tillage and other effective practices cutting erosion.

Studies Showing Macroeconomic Impacts

We now turn to studies which allow some generalization of results of farming practices reducing synthetic chemical use. These studies too have shortcomings as noted.

The first study (see Tweeten and Helmers) is for an experiment in the cornbelt region of eastern Nebraska comparing low chemical use systems to the conventional corn-soybean rotation found in large areas of the U.S. cornbelt. The second is a study by Knutson *et al.* for the United States assuming elimination of pesticides and synthetic chemical fertilizer. The third study is for an incremental change in chemical use.

1. The Nebraska Study. Basic data are from a University of Nebraska study for a cornbelt resource situation in eastern Nebraska (Sahs *et al.*). System (1), a row crop rotation of corn and soybeans, is conventional agriculture.

Gross receipts are found by multiplying the prices given in the footnote times production on 600 acres at the yields indicated in Table 4. Variable operating costs per acre are lower for the alternative agriculture rotations (3), (4), and (5) than for the conventional rotation (1) when compared in a consistent manner. However, costs per unit of output rise for the "low input" systems. For example, variable cost per dollar of output rises from 31 cents for conventional rotation (1) to 40 cents in rotation (5), or by 30 percent.

If a few scattered farms adopted the respective low-input rotations and practices, prices would not change. Under scenario 1, costs do not fall as much as receipts with the low-input rotations so net receipts and net returns to overhead labor and management fall sharply on the 600 acres. If scenario 1 conditions hold, few farmers will adopt alternative agriculture systems because it will not pay to do so. Commodity deficiency payments for feed grains are excluded from the study to more nearly represent market valuation of the output.

Table 4. The Micro and Macro Economics Of Low-Input Rotations In Nebraska.

Item	Crop Rotations[a]				
	C-Sb (1)	Gs-Sb (2)	C-Sb-C-O (3)	S-Sb-C-O (4)	C-Sb-C-O (5)
Herbicide	Yes	Yes	Yes	No	No
Insecticide	Yes	Yes	No	No	No
NPK Source	Fertilizer	Fertilizer	Fertilizer	Fertilizer	Manure
10-Year Average Yields (bu/acre)					
Corn/Grain Sorghum	108.7	88.3	90.5	86.6	84.4
Soybeans	38.0	41.4	37.1	37.0	33.9
Oats	---	---	60.4	60.3	64.6
Acres (assumes 600 acres)					
Corn	300	---	300	300	300
Grain Sorghum	---	300	---	---	---
Soybeans	300	300	150	150	150
Oats	---	---	150	150	150

Table 4 cont.

Item	Crop Rotations[a]				
	C-Sb (1)	Gs-Sb (2)	C-Sb-C-O (3)	S-Sb-C-O (4)	C-Sb-C-O (5)
Scenario 1: Results if only a few farmers adopt alternative agriculture					
Gross Receipts ($)[b]	151,179	133,899	114,652	111,614	114,633
Percent Change from C-Sb	---	-11.43	-24.16	-26.16	-24.17
Variable Costs ($)	46,179	30,699	47,452	42,614	45,633
Net Return above Variable Costs ($)[c]	105,000	103,000	67,200	69,000	69,000
Fixed Costs ($) (Land & Machinery Ownership)	75,000	75,000	75,000	75,000	75,000
Net Return to Overhead Labor & Management ($)	30,000	28,200	-7,800	-6,000	-6,000
Scenario 2: Results if all farmers adopt respective rotations					
Gross Receipts ($)[b]	---	38.10	80.53	87.20	80.57
Percent Change from C-Sb	151,179	184,915	206,981	208,941	206,993
Variable Costs ($)	46,179	30,699	47,452	42,614	45,633
Net Return above Variable Costs ($)[c]	105,000	154,216	159,529	166,327	161,360
Fixed Costs ($) (Land & Machinery Ownership)	75,000	75,000	75,000	75,000	75,000
Net Return to Overhead Labor & Management ($)	30,000	79,216	84,529	91,327	86,360

Source: Saha, W.W., G. Lesoing, G.A. Helmers, and J.E. Friesen, 1988.

[a]C = corn, Sb = soybeans, Gs = grain sorghum, O = oats/sweet clover. Yields from 1978 to 1985/87. Site is Mead, Nebraska. Oat straw, 100 bales per acre, market value.

[b]Average prices per bushel: corn $2.50, soybeans $6.11, grain sorghum $2.19, and oats $1.41. CPI adjusted 1985 base. No government payments. Manure cost 50% of NPK fertilizer; 8.5 tons on corn and 6 tons on oats.

[c]Including costs of direct labor.

The assumption in scenario 2 is that all farmers adopt each respective rotation and that the rotations represent what is happening in the nation. Compared to the conventional system, aggregate output (measured by constant-dollar output = acres x yield x constant dollar prices) falls 11 percent with rotation (2), 24 percent with rotation (3), 26 percent with rotation (4), and 24 percent with rotation (5). In the 3 to 5 year length of run considered, each 1 percent reduction in national output raises price 3.3 percent (an aggregate price elasticity of demand of -0.3 which is consistent with estimates from various sources of the demand for feed grains and soybeans in the intermediate run). The result in scenario 2 is to raise receipts in cases (2) through (5) above those of the conventional rotation (1). Net returns above variable costs (including costs of direct labor) increase and returns to overhead labor and management increase by two to three times compared to rotation (1).

The analysis illustrates the important principle that administratively mandated widespread adoption of practices of alternative agriculture such as possible under a federal farm bill could substantially reduce food output and raise prices and farm gross and net income in the intermediate run. Nationwide adoption of alternative agriculture practices would reduce food output (up to 26 percent using the example herein) and raise food prices, placing a severe burden on budgets of low-income consumers.[10] Food shortages could sharply increase in less developed countries even if only developed countries adopted alternative agriculture systems. American export earnings would fall sharply unless other countries adopted similar practices -- an unlikely situation. Also, the results show that producers presently do not have economic incentives to adopt many low-input systems -- unless they are forced to by public policy.

Shortcomings of the study are numerous:

* Nebraska results may not generalize -- data such as in Table 4 are needed for more resource situations around the country.
* Not all farmers will adopt low-input practices even if mandated by legislation.
* Reliance on manure for fertilizer is not feasible for all farms. Manure would have to be purchased for some farms and transportation costs of manure are high. Inclusion of a livestock

[10] Food price increases are not shown but are approximately one-fourth the increase in farm level prices based on the assumption that farmers received 25 percent of consumers' food dollars. Thus a 20 percent increase in farm prices raises food prices about 5 percent.

system would improve efficiency of the rotations (3), (4), and (5), but many farmers would not include livestock. Large numbers of part-time and low-management capability operators would not participate.

* Variable and overhead costs are assumed to be unchanged in the example with widespread adoption of alternative low-input rotations. Variable costs could rise as manure prices are bid up. On the other hand, chemical prices could fall as many farmers cut use.

* Although some alternative agriculture enthusiasts would ban all chemical use, in reality any policy mandated restrictions are likely to be incremental rather than total.

* Farmers would feverishly strive for improved practices to maintain output with less use of chemicals. Long-term impacts on output and prices would be much less than shown. Good managers would most successfully adjust to change. Some regions such as the Great Plains, which are less dependent on chemicals than the humid Southeast, would fare relatively well as the following more comprehensive U.S. study illustrates.

2. A U.S. study. Based on yield and cost estimates by over 140 agricultural scientists, Knutson *et al.* analyzed the nationwide impact of eliminating synthetic chemical use on corn, soybeans, wheat, barley, cotton, rice, peanuts, and sorghum. These commodities account for 75 percent of agricultural pesticides applied to crops and 70 percent of the inorganic nitrogen fertilizer used in U.S. agriculture. An econometric model was used to trace impacts of zero chemical use on the agricultural and national economies.

Yields and production. Figure 6 for corn illustrates the estimated impact on yield of curtailing various chemical uses. Yields are 48 percent of base levels with no synthetic nitrogen fertilizer or pesticides. No nitrogen drops yield by 41 percent from the base; no insecticides and fungicides drop it only 5 percent.

These results are only suggestive: as noted elsewhere, no influential interest group proposes eliminating all pesticides. Nitrogen fertilizer is even less likely to be proscribed. Interpolation gives approximations for partial controls: elimination of half of all nitrogen fertilizer on corn might reduce yields about 20 percent, i.e., to 80 percent of the base.

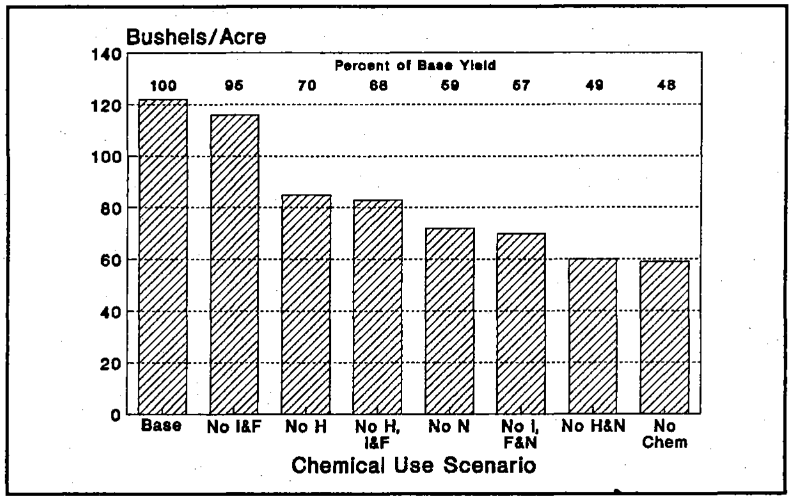

Figure 6. U.S. Yield Degradation Curve for Corn by Chemical Use Reduction Scenario.

Source: Knutson *et al.*, p. 15.

Key: No I & F - No insecticides or fungicides (except seed treatments).
No H - No herbicides.
No H, I & F - No herbicides, insecticides, or fungicides.
No N - No inorganic nitrogen fertilizer.
No I, F & N - No insecticides, fungicides, or inorganic nitrogen fertilizer.
No H & N - No herbicides or inorganic nitrogen fertilizer.
No Chem - No herbicides, insecticides, fungicides, or inorganic nitrogen fertilizer.

Estimated yield and production reductions for selected crops and production reductions for livestock and total farm output are summarized in Table 5. Cotton yield declines sharply; soybean yield falls less because soybeans do not require nitrogen fertilizer. Yield reductions for wheat, barley, and grain sorghum were low because pest and fertility problems are minimal in the Great Plains where most of the crops are grown. Peanut, cotton, and rice yields fall sharply because they are grown in the South where soil fertility and pest problems are often severe. Production falls less than yields due to a 10 percent overall acreage increase, implying soil erosion hazards from more acres in crops. It is questionable, however, whether the analysis adequately accounted for the loss in production of the eight crops as acreage of legumes expanded to supply fertilizer.

Pesticides pose a different threat to food and water safety than does nitrogen fertilizer, hence it is well to separate impacts of the two. Overall crop output is predicted to decline 20 percent with no pesticides and nearly double that (39 percent) with no nitrogen fertilizer or pesticides. Livestock output falls much less -- 2 to 6 percent. Overall farming output of crops and livestock for 1995-98 is predicted to drop 11 percent with elimination of all pesticides and by 22 percent with elimination of all chemicals. It is notable that the latter is very near the impact on output depicted in Table 4.

Table 5. Percentage Reduction in Crop Yields with No Pesticides and No Chemicals (No Synthetic Chemical Nitrogen Fertilizer or Pesticides), U.S., 1995-1998.

	Percentage Reduction 1995-1998			
	Yield		Production	
	No Pesticides	No Chemicals	No Pesticides	No Chemicals
	(%)			
Corn	22	38	18	34
Soybeans	35	35	26	26
Wheat	19	34	8	27
Cotton	39	62	30	56
Barley	26	36	14	32
Sorghum	8	8	0	6
Rice	58	64	40	48
Peanuts	75	75	17	17
Weighted crop total	NA	NA	20	39
Livestock	NA	NA	2	6
Weighted crop-livestock total	NA	NA	11	22

Source: Knutson *et al.*

Production and price changes would be less in the long run because improved farming practices such as use of green and livestock manure could compensate for some of the reduced chemical use. Farmers would be ingenious in finding means to cope with reduced chemical availability, and not all these coping mechanisms would be environmentally benign. Sodbusting, swampbusting, forestbusting, green manure, and sludge have their shortcomings.

Consumer costs. In 1989 dollars, consumer costs per household were estimated to rise by $228 per year if pesticides were eliminated and $428 if nitrogen fertilizers also were eliminated. Low-income consumers would be spending 44 percent of their income on food. The CPI for food was estimated to rise 33 percent with no chemical use. Household income spent on food was estimated to rise 6.5 percent with no pesticides and 12.2 percent with no chemicals.

Exports. Removing pesticides and inorganic nitrogen fertilizer (no chemicals) would reduce grain and cotton export volume by nearly 50 percent. Agribusiness industries engaged in exports would experience major setbacks. The loss in exports would be $14 billion and 217,000 jobs with no chemicals.

Receipts and income. Receipts from the eight crops included in the study were estimated to rise 48 percent and net income by 164 percent. The largest economic gains would be in the North. The Delta (Arkansas, Mississippi, Louisiana) and Pacific regions would incur net economic losses. Livestock producers throughout the nation would incur economic losses.

Farm expenses. With no chemicals, farm expenses would rise by an estimated 6 percent because rising costs for fuel, machinery, interest, feed, and other inputs would more than offset chemical cost savings.

Comment. Because no policymaking body seriously contemplates ending use of all synthetic chemicals in agriculture, the above estimates are meaningful only in indicating *directions* of change with chemical restrictions. The essential lesson from the study is that the nation could experience serious consequences from a policy of rapid shift from conventional agriculture. A more cautious and gradual approach has merit. This would allow substitute technologies to emerge and operators to be trained in techniques to minimize production loss from chemical input restraint.

3. An Ohio study. Critics have strongly attacked studies such as those in Tables 4 and 5 for being too pessimistic on yields and output. A December 1990 Ohio study of actual yields on 90 certified organic farms supports the tables' results (Batte). The survey response rate was 63 percent.

Corn yields per acre averaged 86 bushels on organic farms, 70 percent of the 123 bushel average on all Ohio farms (Figure 7). The highest organic yield was 110 bushels. Organic wheat yields averaged only 73 percent of the state average. But organic oat and soybean yields fared better, averaging 80 and 83 percent respectively of Ohio yields.

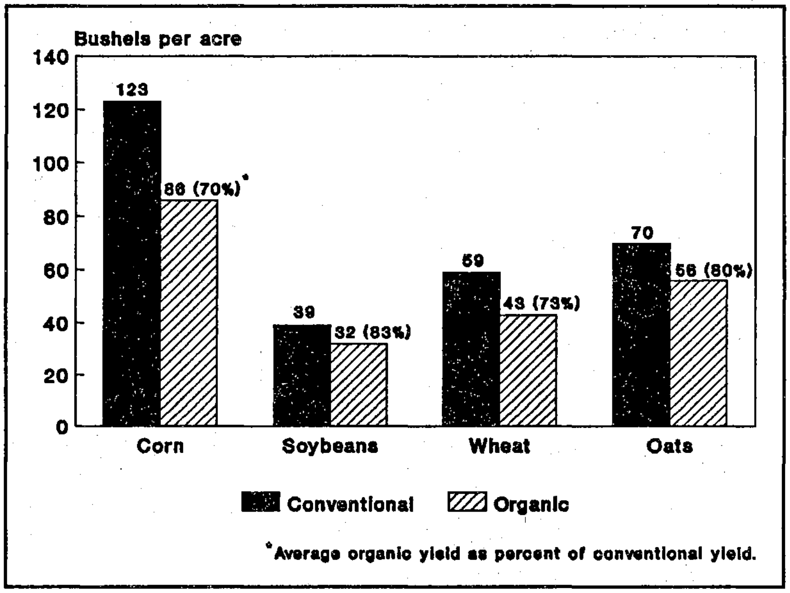

Figure 7. Yields for Conventional and Organic Agriculture, Ohio, 1990.
Source: Batte.

Despite a substantial price premium for organic produce and above average management, at least as suggested by greater average educational attainment of organic farm operators, net farm income was substantially lower on organic than on all Ohio farms. Adjusted gross income per family was not much lower than on all Ohio farms because organic farmers' off-farm earnings were especially large.

It is hazardous to infer results for sustainable agriculture from results for organic agriculture. But the Ohio study suggests that considerable improvements in managment and technology will be necessary to obtain the synergisms of Figure 1 essential for sustainable agriculture to meet the competitiveness needs of farmers and food needs of consumers at home and abroad at reasonable cost.

Crop responses for more modest reductions in chemical use are quite different than the zero-application found in many of the above studies. Helmers *et al.* (p. 5) estimated that a 10 percent reduction in total fertilizer and pesticide use could reduce U.S. wheat production by 1.3 percent and soybean production by 2.2 percent. Feed grain production was estimated to increase. Market prices of wheat, soybeans, and feed grains were estimated to rise .8, 1.6, and 2.8 percent respectively.

In concluding this subsection, it is necessary to recognize that fertilizer and pesticides on average are highly productive farm inputs. It is not possible to reduce their use significantly without a sizable reduction in food output.

Fertilizer, Pesticides, Fuel, and Electricity Efficiency by Farm Size

The final economic issue addressed in this section is efficiency of input use by size of farm. Some alternative agriculture activists advocate a return to small farms to save energy and chemical inputs. At issue is efficiency of input use by size of farm.

Fertilizer, pesticides, fuel, and electricity not only are derived largely from petroleum and products but also are characterized by finite availability. Other things equal, we would prefer to emphasize production on farms having low costs of these inputs per unit of output.[11]

Figure 8 indicates that large farms use approximately 10 cents of these inputs per dollar of output compared to nearly 50 cents per dollar of output on small farms. The conclusion is that a low input agriculture is not consistent with a small farm agriculture (see Tweeten, 1983; 1984).

Transportation is a major reason for differences in energy costs among farms by size. Commuting costs for work, shopping, car pooling, and related uses do not vary much *per farm* by size of farm. But overall energy costs are far lower having ten 1,000-acre family farms rather than 100 ten-acre small farms occupying a 10,000 acre area. In the latter small-farm case, approximately ten times as many families are commuting. Transportation costs tend to be less when families on small farms live in the towns, suburbs, and cities where they work, shop, socialize, and attend school.

Figure 9 showing components of Figure 8 indicates especially large economies of size in electricity and petroleum fuel as expected based on the previous paragraph. But economies of size are also notable in commercial fertilizers. Agricultural pesticide use declines per unit of output going from small to large farms but not by as much as the other categories in Figure 9.

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[11] Output in Figures 8 and 9 is measured by crop and livestock receipts less feed, seed, and livestock inputs purchased. Other measures of output such as (a) total farm sales, and (b) total crop sales were compared and showed even greater economies for large farms.

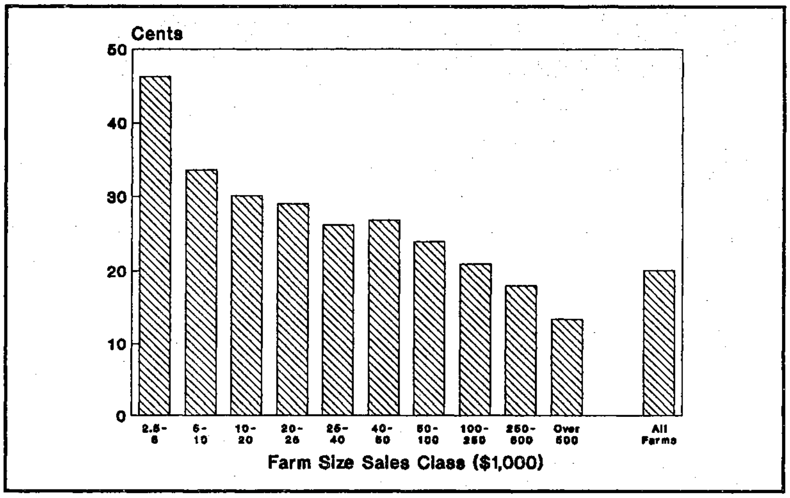

Figure 8. Total Fertilizer, Pesticide, Fuel, and Electricity Expenses Per Dollar of Net Farm Sales by Farm Size Sales Class, 1987.[*]
Source: U.S. Bureau of the Census, Census of Agriculture, 1987.
[*]Net farm sales is gross farm output less feed, seed, and livestock input purchases.

The structure of output is not similar among farms with $10,000 to $250,000 in sales and is most dissimilar comparing very large and very small farms. However, economies of size remain apparent even if comparisons are restricted only to homogeneous-output medium-size farms in Figures 8 and 9.

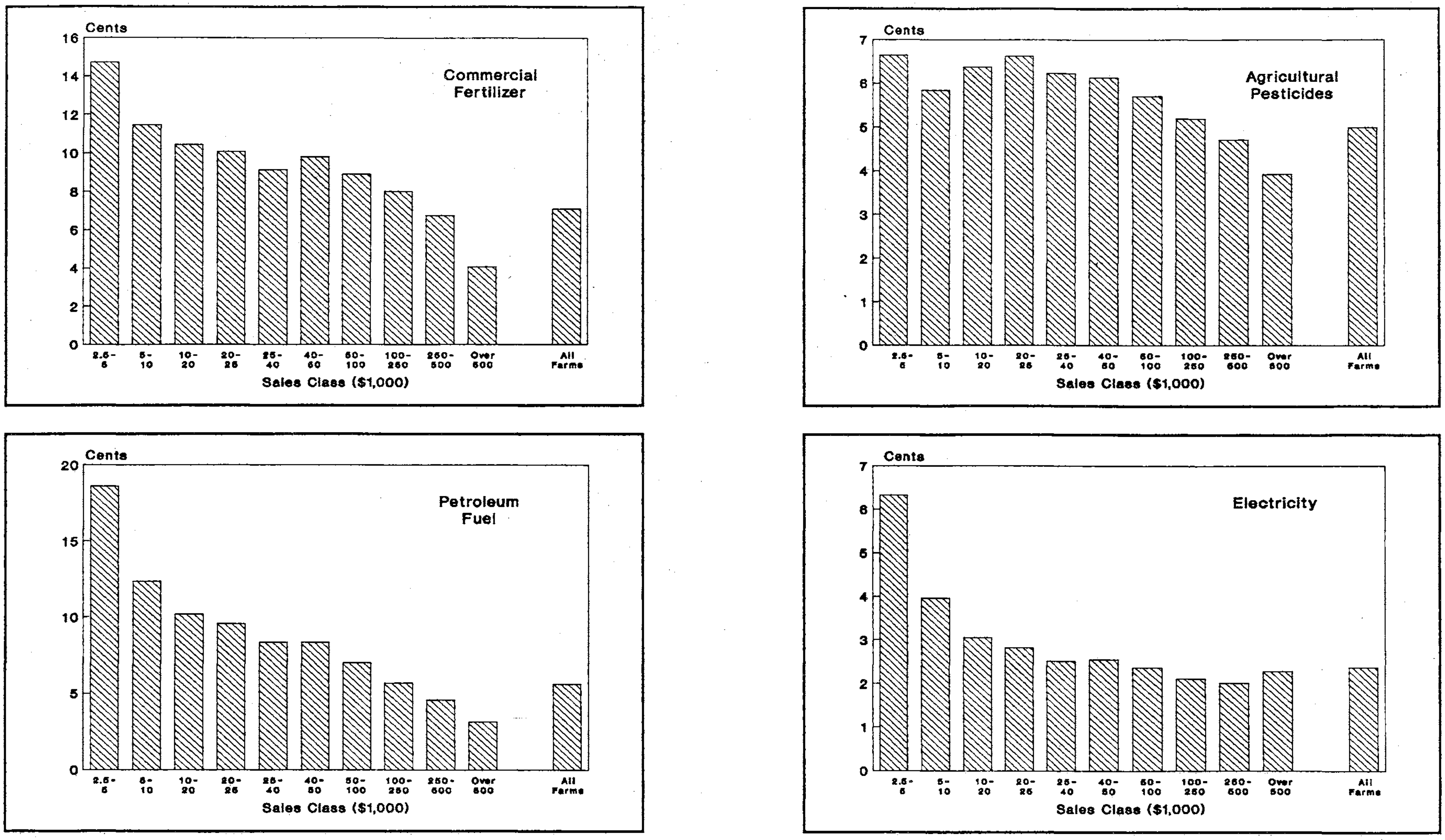

Figure 9. Chemical Inputs Per Dollar of Net Farm Sales by Farm Size Class, 1987.
Source: See Figure 7.

Conclusions and Policy Recommendations

This representative but not exhaustive review reveals large gaps in knowledge of the economics of ESA. In response to my request for data, an agricultural economist who has worked longer than most anyone in the profession with alternative agriculture gave a puzzling response: "I have severe problems with economists who pretend to have the data to make economic comparisons of alternative agriculture when the data do not yet exist."[12] The problem is that data for the synergistic system in Figure 1 are fragmentary and from uncontrolled case studies while the "generalizable" large studies of withdrawing chemical inputs do not account for the synergism in Figure 1. The absence of reliable economic evaluations reflects the larger reality that sustainable agriculture as a synergistic system has not yet been perfected. The only successes are unique cases not yet generalizable.

Policy decisions will continue to be made in this world of too little knowledge of alternative agriculture. The appropriate policy in those circumstances is to create a policy *system* that will allow producers and markets to act in the public interest by making wise individual decisions whether to adopt or reject alternative agriculture techniques based on the merits of each unique situation.

Specific Policy Suggestions

1. Improved chemical testing procedures, screening of chemicals, banning of those failing risk-benefit tests, controls for proper use of chemicals, and education of applicators are useful measures. However, the market with appropriate tax and subsidy incentives is the most efficient and effective means to guide use to less toxic chemicals and to conserve petroleum inputs. With correct prices and education, most producers will act in their private interest which in turn will be in the public interest. A major issue beyond the scope of this paper is

[12] He did not note that many studies do exist but not of comparisons between conventional agriculture and alternative agriculture with the latter using all the latest technology, management, and synergisms. As long as the complete alternative agriculture system remains an art rather than a science to true believers, for them no valid economic comparisons will exist!

how to internalize off-site erosion and other environmental costs which vary widely from farm to farm both in physical volume and damage cost per unit of volume.

2. The terms *low-input sustainable agriculture* and *alternative agriculture* do not properly describe either the systems the terms are supposed to represent or the needs of food and agriculture. Nearly all farmers use some aspect of sustainable agriculture; few if any farmers follow all aspects of the sustainable agriculture system. Nor are many farmers likely to adopt the entire package. The goal is an *environmentally sound agriculture*, not any one set of practices. The goal is productivity growth over the long run, not a static vision of sustainability. The scope and focus of research and other public outlays is quite different with a goal of long-term growth and productivity versus mere sustainability. This issue of science, research, and technology is so important that a later subsection is devoted to it.

3. Changes are needed in the way chemicals are tested and classified.

    * Chemicals which are carcinogenic only because they cause cell damage in massive doses need to be classified differently from chemicals which are carcinogenic at lower doses likely to be consumed by humans. The former need less control but chemical company workers, applicators, and others potentially exposed to large doses need protection. Chemicals carcinogenic in low doses can be banned unless mitigated by benefits. Risk-benefit analysis needs continuing refinement to evaluate options.
    * The double standard for natural and synthetic carcinogens cannot be defended. Chemicals occurring naturally in foods for the most part have not been tested for carcinogenic properties. They need to be tested and screened by the same processes used for synthetic chemicals -- to the extent testing resources and reliability are feasible.
    * In risk-benefit analysis, tradeoffs need to be considered. For example, greater consumption of fruits and vegetables (made possible by lower production costs due to synthetic fertilizers and other chemicals) supplies anticarcinogenic fiber, vitamins, and

reduces natural carcinogens -- all of which lowers risks of cancer and heart disease. Other synthetic chemicals reduce morbidity and mortality from food poisoning. Many foods are highly valued for their taste and aesthetic value despite carcinogenic properties. In many cases the appropriate action is to inform people of the dangers and let them make their own subjective benefit-cost evaluation before consuming the product. Greater use of product labeling is warranted.

* Public testing and control of carcinogenic substances need to be improved. Ames and Gold (p. 971) conclude that "there is no convincing evidence from either epidemiology or toxicology that they [pesticide residues in soil and water] are of interest as causes of human cancer." One of the reasons for the excellent record of food safety is that the most toxic chemicals have been banned and others have been controlled. Some of the millions of dollars devoted to control of minimal-toxicity synthetic pesticides might well be devoted cost-effectively to other mortality-reducing measures such as improving diets (fewer overall calories, more fiber, less fat, alcohol, and sugar), reducing smoking, safer cars and highways, and less drugs and crime.

4. Mandatory regulations and controls need to be the last resort. Some local resource situations face especially acute environmental hazards and will not be protected from toxic chemicals by a tax or from soil loss by subsidies and technical assistance to encourage superior practices. For these, specific mandatory regulations are unavoidable.

5. Greater attention needs to be given to future resource constraints. Limits on national and international soil, water, petroleum, and phosphate reserves are no basis for panic but neither do they warrant complacency (see CAST, 1988). With natural as with environmental resources, the appropriate policy is reliance on the market supplemented by taxes and subsidies where necessary to give proper rationing signals to producers and consumers. In addition, essential public programs include information and research to develop substitutes and in other ways reduce conventional resource constraints.

6. A recurring claim is that we are "exporting soil" because of erosion on land used to produce commodities for exports (see Doering *et al.*). From this correct assertion, analysts often go on to call for a tax on exports to align social and private costs. They overlook several facts. One, erosion is the same on the portions of a crop destined for domestic use or export, justifying equal treatment. Second, erosion differs markedly among the geographic origins of exported crops. For example, some wheat is exported from flat Great Plains land with no chemical use or erosion. Other exported wheat is from hillsides in the Southeast where erosion and chemical use is high. If erosion is a problem for a commodity domestically consumed or exported, that erosion should be controlled by site-specific policies and not by a "shotgun" export tax. A uniform tax does not properly charge for nor discourage downstream pollution from nonpoint farm sources. Targeted, site-specific controls are necessary in such cases.

7. Conflicts between wise resource use and current policy can be reduced:

* Irrigation water subsidies and depletion allowances encourage excessive resource use and production. At the same time, other public programs pay farmers not to produce. Farm water subsidies divert water from urban uses of much greater value.
* The Environmental Protection Agency's chemical review process discourages replacement of toxic pesticides registered under more lenient past procedures with more environmentally benign new chemicals which are too costly to register under today's more extensive requirements.
* Antagonisms between agriculturalists and environmentalists are a cause of underfunding of "conventional" basic and applied agricultural research essential for safe, low-cost, abundant food supplies placing fewer demands on fragile resources. Antagonisms detract from following a coherent, rational policy to simultaneously raise productivity and protect the environment.
* Commodity program conflicts are discussed below.

Farm Commodity Programs

Whether farm commodity programs are net contributors or detractors from ESA remains debatable.[13] What is not debatable is that federal budget stringency has forced restructuring of major commodity programs. Suggestions for future revisions are offered below:

1. Farm legislation needs to separate commodity programs from environmental programs. Combining them serves well neither farm income enhancement nor environmental goals. With commodity program benefits declining, participation rates will decline. Fragile land should not be excluded from environmental programs simply because the operator does not choose to participate in commodity programs. Environmental programs to conserve soil and avoid food and water contamination are more important to the future of agriculture and society than are commodity programs. An alliance of the powerful environmental and farm lobbies could perpetuate outdated commodity programs and untargeted, cost-ineffective environmental programs.

2. Given (1) it does not follow that commodity programs should be allowed to promote environmental degradation. Market economists and environmentalists alike agree that producers need greater flexibility in programs. Programs should not penalize producers for not planting program crops, for accepting lower yields (to save costs, to reduce soil erosion, or to reduce chemical use), or for legume rotations in a crop-livestock system. Some types of programs are more compatible than others with environmental goals. Politicians and producers may be attracted to mandatory controls to raise farm income at low government expense when program funds are short. But mandatory supply controls are environmentally damaging because they promote high yields and hence chemical dependency.

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[13] Much space in *Alternative Agriculture* (NRC) was devoted to damage done to the environment by farm commodity programs. To John Pesek, chairman of the committee that authored the report, the federal government's culpability was the greatest discovery of the five year study (La Ganga and Savage, p. 26). Commodity programs do indeed encourage farmers to achieve high yields by applying fertilizers and pesticides at considerable social cost in groundwater and surface water and crop residue pollution from programs. But the study overlooked the fact that acreage reserve programs have reduced land in crops and erosion. The net effect of commodity programs on the environment is unknown.

If supply must be controlled, marketing quotas (as opposed to acreage quotas) allow more input substitution and a least-cost input mix compared to acreage controls, hence are preferred to an acreage control program. Studies demonstrate that a relatively few high-cost producers account for a disproportional share of chemical input use (Glaze and Ali). Hence a free market without controls and resulting in prices low enough to eliminate such production is consistent with environmental stewardship. If deemed necessary, decoupled direct payments can supplement farm income in transition from commodity programs. Paid diversion programs are more cost-effective in using limited program funds to raise farm income than are direct payments, but unfortunately encourage chemical use to raise yields and are not easily targeted to the needy.

3. Triple-base or normal cropland acreage (NCA) plans have much to recommend them. The triple-base plan frees some portion of a farmer's current grain or cotton base for "flex acres" to be devoted to any use desired by farmers (except fruits and vegetables in the 1990 farm bill) without further loss of deficiency payments or base history. A superior alternative approach, the normal cropland acreage base, would combine all crop bases and rotation pasture in a single aggregate NCA. After devoting some portion of that NCA to soil conserving uses, the producer could utilize the remaining land as desired (e.g., for grass, trees, rotations, crop-livestock systems, or recreation) without loss of deficiency payments or base history. The triple-base plan of the 1990 farm bill is a step forward but extension of grain, cotton, and soybean loan rates to all program acres including flex acres is a mistake. Loan rates only for acres covered by deficiency payments would reduce market distortions.

4. Environmental programs need to be *targeted* for cost-effectiveness. The Conservation Reserve Program (CRP) currently removes millions of acres of land not subject to erosion along with acres subject to erosion. Greater emphasis on diverting parts of farms and parts of fields would secure more environmental impact per dollar of program cost. Supply control can be a subordinate objective of CRP.

5. Environmentalists and economists need to work together for sound commodity programs. Market economists have long recognized inconsistencies of commodity programs with wise use of natural and environmental resources. Environmentalists belatedly are recognizing these same inconsistencies. Good economics and good environmentalism do not conflict. Both traditions see merit in de-emphasizing supply controls, increasing cropping flexibility, ending export subsidies, and correcting externalities.

Science, Research, and Technology

The critical importance of appropriate research was noted earlier but deserves elaboration, particularly regarding the role of the public sector.

1. Review of economic studies strongly indicates that, with technology available to date, alternative agriculture systems that substantially reduce synthetic chemical use would curtail agricultural output and raise food prices. A very successful ESA depends on research to develop biological pest control, pest-resistant plants and animals, nitrogen-fixation capability in grains and other grasses, and higher yielding plants and animals. Adequate research will not be forthcoming from private agribusiness firms or individual farmers alone; basic and adaptive publicly supported research is essential to meet the twin goals of protecting the environment while serving consumers' needs.
2. Publicly supported agricultural extension and research can be more supportive of environmentally sound systems than they have been. However, the whole-farm systems approach does not lend itself to the scientific method of experimental design and control used by land-grant universities. Much of the whole farm research should be left to producers with, in some cases, public funding and technical assistance from scientists. Scientific research establishments need to focus on the basic individual technologies required for whole farm systems to be technically, economically, and environmentally viable.

3. Future productivity advances necessary to avoid real food price increases cannot be taken for granted. Under-funding of basic research, constraints on release of improved technologies, and redirection of significant amounts of research away from efforts to enhance productivity could result in an unsustainable agriculture and higher real food prices.

   Underinvestment in basic, maintenance, and other types of agricultural research is substantial, especially at the federal level. The past scientific revolution of hybrid varieties, commercial fertilizers, and the tractor (and complements) displays diminishing returns (Tweeten, June 1989). If current trends continue, rates of gain in productivity by year 2000 will have slowed to half the rate in 1950 for several crops and livestock. Benefits from growth hormones and other products of biotechnology are being delayed by legal confrontation over environmental and socio-economic effects.

4. The public research-extension system and the private sector recognize that a strong demand exists for a new generation of technologies. Ideally, these technologies will be soil and water conserving; fertilizer, petroleum, pesticide, and food additive reducing; diet (less fat, more fiber) and animal welfare enhancing; and family farm and small rural community preserving. If technologies do not possess all these properties, alternative agriculture activists may be tempted to block access. Compromises will be necessary.

   Farmers' income goals and environmental goals are not necessarily in conflict. Of course, farmers fear capricious and arbitrary rules regulating chemical use, wetlands, and animal rights. The most reliable economic analysis to date indicates that many measures advocated by environmentalists are unprofitable if adopted by a few individual farmers but are profitable if many farmers adopt, thereby reducing output and raising prices and profits. Not all farmers would be winners, and consumers would often be losers.

5. Some analysts (see Reichelderfer, p. 216) contend that the failure of voluntary programs to bring a safe environment will motivate mandatory regulations. The 1990 farm commodity program provides no evidence that the stick has replaced the carrot in environmental policy.

> The requirement that farmers keep records of chemical use establishes a data base for stricter controls ahead, however.

Dating at least as far back as Parson Thomas Malthus over two centuries ago, Cassandra doomsdayers have contended that the world is losing the capacity to feed itself, that technological improvements will not be sufficient for food production to keep up with population gains, that environmental degradation will ravage food output, and that poverty, hunger, disease, and war must restrain food and water demand.

Pollyanas, on the other hand, have contended that environmental and resource depletion issues can be ignored and that science and industry can be counted on for a technological fix to every ill. Neither the Cassandra view nor the Pollyana view is supportable. There is reason for concern but not panic about future food and water supplies.

Success will not happen by chance. While it is critical to rely heavily on the market, it is also important for the public sector to conduct basic research, monitor environmental conditions and food safety, and use taxes, subsidies, and regulation prudently to encourage individuals and private firms to act in the public interest. Given supportive public policies, Americans can continue to have the safe, varied, abundant, and low-cost food and at the same time can protect the environment.

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