THE CHANGING DYNAMICS OF GLOBAL AGRICULTURE

A Seminar/Workshop on Research Policy Implications for National Agricultural Research Systems

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Session III
Sustainability of Agricultural Production Environments

The Agricultural Sustainability Issue: An Overview and Research Assessment

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Introduction

There is a growing and diverse literature based on agricultural sustainability – concerning its meaning, relevance as a concept in agriculture and development, and applicability for research planning and extension activities. Some confusion comes from the fact that the term has intellectual (and emotional) roots from different disciplines where it is used in a variety of contexts (Brown et al., 1987).

By way of introduction, I discuss several meanings of *sustainable*, then, of *agricultural sustainability*, followed by a look at our current agricultural system and what the impetus is to change it. Then, I report the state of the art in research on low-input, sustainable farming systems and consider what impediments there are for farmers to change from current agricultural production systems. Finally, I conclude by looking at the agenda for change and note that any transformation is more likely to be gradual than abrupt.

Perceptions of 'sustainable'

Sustainable to some means survival – barely hanging on. A subsistence-level or sustenance-level livelihood is endured by much of the world's population.

The term *sustainable* has long been used by resource managers with reference to the maximum harvesting of forests or fisheries consistent with the maintenance of a constantly renewable stock. The same concept applies to the optimal use of a groundwater aquifer. *Sustainability* is the steady state when what is being used (harvested) is continually replaced.

Sustainability has been defined by some in terms of carrying capacity (a term developed by population biologists) – the maximum population size that the environment can support on a continuing basis. As one would expect, calculation of carrying capacity for society on a regional or global basis is exceedingly difficult because "quality of living" must enter the equation.

Lester Brown (1981) sees a sustainable society as enduring, self-reliant, and less vulnerable to external forces. He optimistically asserts that this can be accomplished with regulations, efficient use of resources, conservation, and a stationary, dispersed population with less affluent lifestyles.

Conventional economic theory has a more neutral outlook lacking a direct counterpart to sustainability. Given the proper social discount rate, resources, properly priced, can be allocated efficiently to yield their highest return over a specified time horizon. Technological innovation is an integral part of the theory dispelling great concern for natural resource exhaustion and for the environment's potential degradation. Hence, with occasional technological breakthroughs, population growth is not inconsistent with economic growth, nor with a dynamic market equilibrium. Distinguishing between public and private costs is a key problem, however, in dealing with environmental degradation.

The concept of agricultural sustainability

With this general discussion as background, we turn to the concept of agricultural sustainability. Other terms for agricultural sustainability include alternative, regenerative, low-input, ecological, environmentally sound, and even organic agriculture. These terms are used by people interested primarily in alternative systems of farming that will feed expanding populations while minimizing potential negative effects, whatever they might be. Defining the negative effects essentially separates or categorizes the various proponents of sustainable agricultural systems. Some groups put primary emphasis on minimizing environmental damage and degradation. Sustainability becomes almost synonymous with stewardship of the earth. Others want mainly to perpetuate a rural community system; community sustainability or maintaining viable rural communities becomes almost a goal in itself. Still others equate agricultural sustainability with food self-sufficiency while minimizing costs. Many advocate an energy-conservation agriculture – so much so that efficiency of the system is measured exclusively in terms of energy use. People require both safe food and water, which in turn, proponents argue, require an agricultural system that can operate ad infinitum with only meager dependence on inputs external to the farm. Thus, just as the term *sustainability* has differing dimensions in various contexts, the agricultural counterpart has social, ecological, economic, and emotional connotations.

Harwood (1987) listed the following dimensions of the agricultural sustainability concept, important for both the developed and developing world:

- *The time dimension.* Farmland preservation and soil conservation continues over centuries toward distant horizons.

- *Social sustainability.* The farm family and traditional rural community are believed to be able to endure over time, even with changes in the general farm economy.

- *Economic sustainability.* The farm unit is expected to remain economically viable in the long term; smallness and diversification are emphasized.

- *Maintenance of soil and genetic resource bases.* A diversified gene pool is a buffer necessary for long-term survival.

- *Minimization of environmental pollution.* The changing human/land ratio means increasing demand for clean water and reduction of biocides in the environment.

- *Lowered use of industrial inputs (fertilizer, pesticides, etc).* Reduced agricultural chemical usage is needed to lessen adverse environmental impact and relieve demands on the fossil fuel supply.

To summarize, Harwood argues that "a sustainable agriculture must make optimal use of the resources available to it to produce an adequate supply of goods at reasonable cost; it must meet certain social expectations, and it must not overly expend irreplaceable production resources."

Madden (*in press*), who has written extensively on this subject, gives a slightly more restrictive definition: "The ideal or norm is characterized as a farming system in which an abundance of safe and nutritious food and fiber is produced using farming methods that are increasingly sustainable, profitable, and ecologically harmless." Madden doesn't specifically mention the social aspects of sustainability.

Liebhardt (1987), director of the University of California Agricultural Sustainability Program, is more succinct, noting that sustainable systems tend to minimize the use of external inputs and maximize internal inputs which already exist on the farm.

Given the heuristic nature of these definitions, it is understood why the paths to sustainable outcomes are not clearly marked. Douglas (1985), in a conference presentation entitled *Sustainability of What? For Whom?* notes that even our knowledge about the limits or break-points of overstressed natural support systems is very meager. Yet, further reflecting on the definitional imprecision of agricultural sustainability, Douglas asserts (laments?) that "it ought to be possible to construct a set of techniques, institutions, and public policies that move us toward outcomes that reflect consistent economic, ecological, and community goals." He concludes with an admonition that research scientists must at least try harder to anticipate and minimize the adverse consequences of potential new technologies and designs.

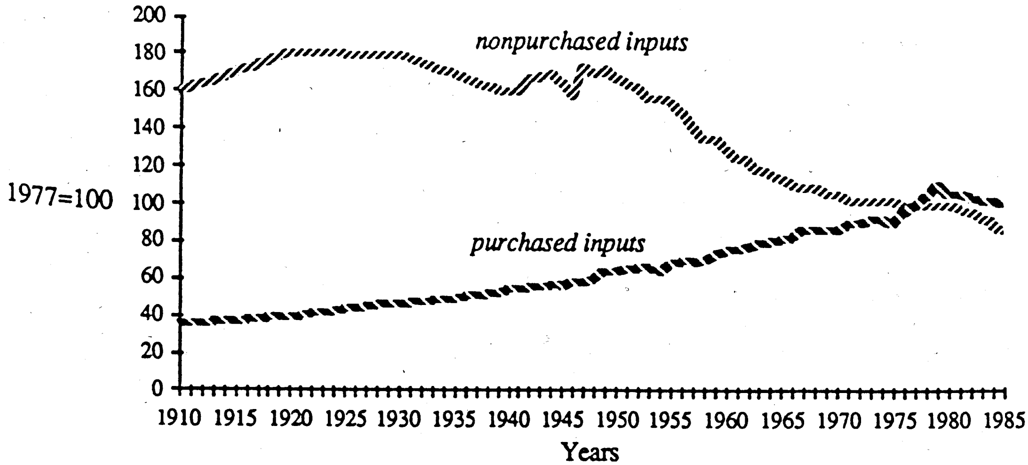
The Current Agricultural System

Perhaps before we assess alternative agricultural systems, we should briefly examine the record of the existing system. A succession of new technologies has helped transform societies over the last few centuries from predominantly rural to urban. The heavy plow was introduced in northern Europe along with the harness and nailed horseshoe, resulting in a doubling of agricultural productivity with horses over that with oxen (White, 1962). Mechanical power replaced the horse early in this century, resulting in further productivity gains and releasing vast amounts of land for food production that were formerly used to produce animal feed. Over the last half century, the revolution for the developed and, to a lesser extent, the developing world has been in terms of chemical technologies applied to agriculture. The productivity gains have been indeed impressive. The next technological revolution is expected to come from the "new" biotechnology, particularly recombinant DNA.

What are the trends in input use since the turn of the century? Figure 1 shows the dramatic downward trend in nonpurchased farm inputs (i.e., those produced on the farm) and the upward trend in purchased inputs (the fertilizers, pesticides, equipment, machinery, hired labor, etc.). Daberkow and Reichelderfer (1988) calculate that since 1900, total production expenses in the United States have grown from 45% to over 80% of gross farm income. Between 1950 and 1985, manufactured inputs, interest and capital related expenses as a share of total production cost almost doubled (from 22% to 42%), whereas labor and farm-origin input expenses declined from 52% to 34%. Similar trends are found in other developed regions and in the developing countries with the greatest productivity gains. Sustainable systems that tend to minimize the use of external inputs and maximize the internal inputs that already exist on the farm must find a way to reverse these near century-old trends.

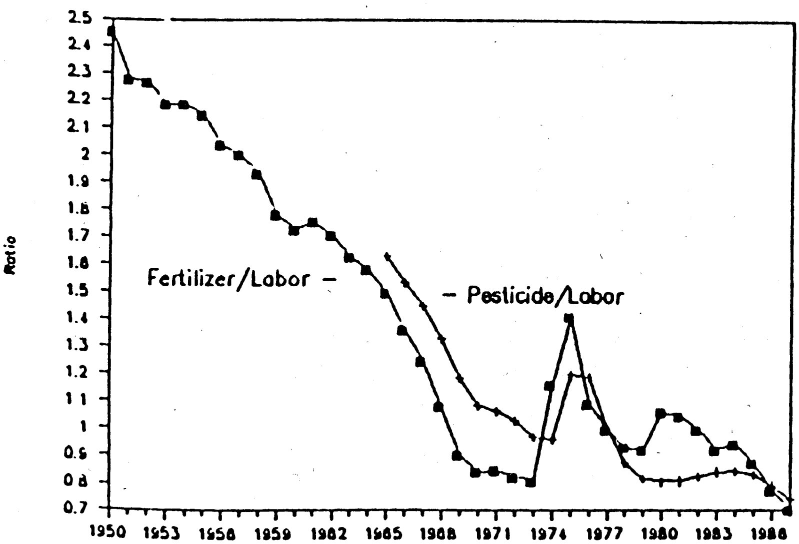
Relative prices are an important factor in farmers' decisions to shift to (or from) energy-intensive production. Daberkow and Reichelderfer (1988) explored price relationships between various chemicals and other substitute factors. During most of the last four decades, both farm wage rates and the price of farm machinery increased at a faster rate than farm chemicals (Figures 2 and 3). These data show that agrichemicals became relatively less expensive over time; fertilizer and pesticides became cheap substitutes for competitive factors and were attractive adjuncts to complementary factors. Thus, price incentives have contributed importantly to increased chemical usage in the postwar years; these high chemical application rates have been only slightly moderated recently, due in part to declining product prices.

Figure 1. Indices of farm purchased and nonpurchased inputs, United States, 1910-1985



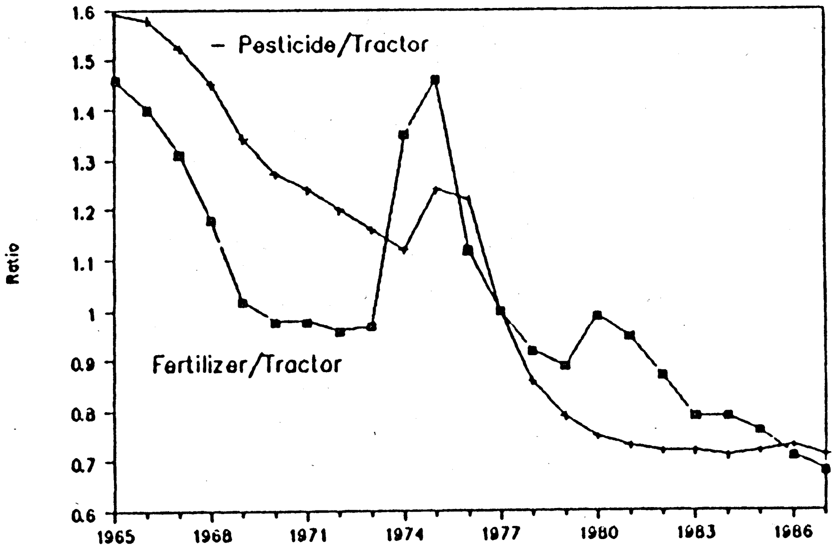
SOURCE: USDA (1986).

Figure 2. Ratios of fertilizer and pesticide price indices to the farm wage rate index in the United States, 1950-1986



SOURCE: Daberkow and Reichelderfer (1988).

Figure 3. Ratios of fertilizer and pesticide price indices to the tractor price index in the United States, 1950-1986



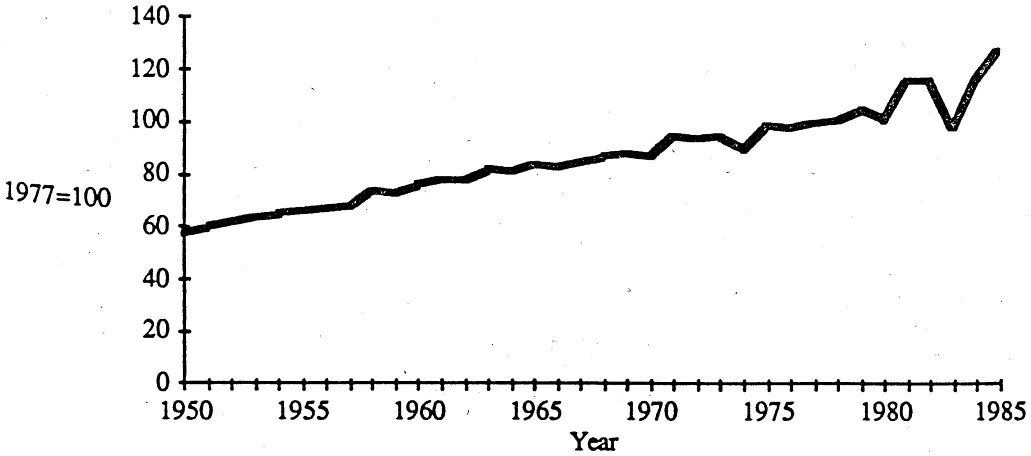
SOURCE: Daberkow and Reichelderfer (1988).

This conventional agricultural system that has relied heavily upon purchased inputs of fertilizer, pesticides, and other energy-intensive factors is considered a success story in terms of traditional measures of output and productivity (Figure 4). The food crises and regional famines that have occurred periodically throughout history have not been from lack of global agricultural production capacity. Better distribution of the abundance remains a key social and economic challenge.

This century began with a world population of around 1 billion. It is projected to end with close to 5 to 6 billion people. Yet, the Malthusian prophesy remains unfulfilled largely because of a succession of new technologies that have continually expanded the productive capacity of the global food and agricultural system.

Before the recent drought, U.S. overcapacity was about one-third of recent annual production of corn, wheat, and rice and about 10% of total annual dairy production (U.S. Council of Economic Advisors, 1987: 147-178). But, in contrast with earlier decades, the current overcapacity extends far beyond U.S. borders to most of the

Figure 4. Farm productivity: Index of output per unit of input, United States, 1950-1985



SOURCE: USDA (1986).

developed world. During the 1980s, world stocks of sugar have risen 45%; world butter stocks amount to about one-third of total annual consumption. World wheat stocks held by major exporters had increased by two-thirds between 1981-82 and the end of 1985-86. During this period, the U.S. share of world wheat stocks increased from 50% to 62%, the equivalent of two years of domestic consumption. At the end of 1986-87, it is estimated that the United States held about three-quarters of the world stocks of coarse grains, which represents about one year's domestic consumption. Admittedly, the growth in stocks reflects in part the policy choices made by developed nations to protect their farmers from the realities of the world market; yet they also attest to the productivity success of the conventional agricultural system.

And the current abundance is not a phenomenon seen only in the developed countries but in parts of the underdeveloped world as well. Avery (1988) shows that many developing countries are participating in the global expansion of agricultural output. He cites the dramatic turnabouts in India, China, Bangladesh, and Indonesia that defied some "experts." India, for example, was characterized two decades ago as a hopeless "basket case" by the Paddock brothers (1967) in their book, *Famine-1975!* In the 1980s, India has sold wheat surpluses abroad. Only very recently – since the late 1970s – China has made a great agricultural leap forward and now competes with U.S. farmers on cotton and grain export markets. Similarly, Brazilian soybeans and Argentine grain are now marketed internationally. The Green Revolution that has so

Table 1. Growth rates for agricultural production

Region[1]	Growth rates (percent per year)			
	1951-60	1961-70	1971-80	1980-84
Developed countries	2.5	1.9	1.8	1.1
Developing countries	3.1	2.7	3.2	3.0
Latin America	3.3	2.7	3.5	0.0
Mexico	5.3	4.0	2.8	−1.0
Brazil	5.1	2.7	4.4	1.7
Argentina	2.0	2.1	4.4	0.5
Middle East	4.2	3.0	3.8	−0.6
South Asia	3.3	2.5	1.8	1.5
India	3.4	2.1	2.4	2.4
Southeast Asia	2.8	4.2	4.6	2.3
East Asia	5.1	4.4	4.7	−0.2
Indonesia	2.9	1.7	4.2	4.2
People's Republic of China	1.7	2.0	1.9	5.2
Africa[2]	2.9	3.0	1.1	1.6
Sub-Saharan Africa[2]	3.1	2.2	1.5	1.7

SOURCE: USDA (1981 and 1985).
1. Country groupings are as defined by the U.S. Department of Agriculture.
2. Excluding South Africa.

greatly increased the world's grain supply, and applications of biotechnology to plant and animal agriculture, promise more.

On an aggregate basis, worldwide, there has been an upward trend in food production, both on an absolute and a per capita basis. Total food production doubled between 1950 and 1984, yielding a yearly compound growth rate of about 2.6%. Perhaps it is more revealing and of some concern to view food production growth rates incrementally over time (Table 1). In the developed regions, growth rates each succeeding decade have been falling consistently since 1950. The developing countries show considerable variability over time with an overall long-term rate close to 3%. The aggregate performance of the developing countries, however, is enhanced by the strong growth in a few large regions – the People's Republic of China, India, and

Indonesia. Meanwhile, growth rates in Latin America, the Middle East, and elsewhere in the developing world have dropped markedly. Given these declining growth rates in the developed and much of the developing world, a closer examination of the current intensive system of production in terms of long-term success in meeting needs may be required.

What Is the Impetus to Change Our Current System?

Thus, despite the impressive picture painted of productivity gains under the current agricultural system and the hopes for continued or even expanded growth as expressed by Avery (1988) and others, the rate of increase in food productivity has been diminishing (Table 1). Does this portend some approaching capacity limits to productivity gains from high-tech agriculture? What other concerns about conventional production technologies in farming for developed and developing countries are being raised? A list includes the following:

Groundwater contamination. Groundwater contamination occurs from the leaching of agricultural chemicals and by-products into the underground aquifers used as a source for drinking water. In the United States, residues of 17 different pesticides have been detected in groundwater in 23 states (EPA, 1985). About one-third of all U.S. counties are vulnerable to groundwater contamination by pesticides (Nielsen and Lee, 1987). Some data indicate pesticides in the drinking water of over one-fourth of the people in Iowa (Crosson and Ostrov, 1988: 13-16). California's Proposition 65, the Safe Water and Toxic Enforcement Act of 1986, holds industries, including agriculture, directly accountable for their use of chemicals that can cause cancer, birth defects, and sterility.

Food safety – Pesticide residues on agricultural commodities. A number of recent consumer attitude surveys have revealed that pesticide residues are judged to be a serious hazard to health (Food Marketing Institute, 1987: 32). In fact, many consumers tend to be more worried about pesticides than about hazards that food safety experts feel are much more serious (e.g., fats and cholesterol, microorganisms) (York, 1987). There has recently been a spate of publications on the subject, attesting to – or raising – the concerns of U.S. consumers. Among them: *Leaching Fields* (California Assembly Office of Research, 1985), *Regulating Pesticides in Food: The Delaney Paradox* (National Research Council, 1987), *Pesticide Alert* (Mott and Snyder, 1988), and *The Invisible Diet* (Price, 1988). The University of California Agricultural Issues Center sponsored a year-long study looking at all the ways various agricultural chemicals find their way into our food supply, what the risks are, and what should be done about it.

The health and safety of farm workers. There is more definitive knowledge about pesticide-related illness among farm workers. Many argue that worker safety is of a higher priority than food safety in reference to agricultural chemical usage. Quoting Donald Kennedy (1988), president of Stanford University: "a careful look at the problems of occupational health and problems of consumer health reveals that they are not the same. Persistence is an important feature of pesticide risk to consumers; but the occupational threats to production workers, applicators and agricultural field workers relate much more to immediate toxicity. Thus the organophosphate insecticides, if proper reentry times are not observed, constitute major occupational hazards – but owing to their rather quick degradation they are not the major problems for consumers." In California in 1986, 1,065 cases of pesticide-related occupational illness were confirmed by the state – nearly all were among agricultural workers (Stimmann, 1988).

Wildlife and natural species endangerment. Environmental contamination from agricultural chemicals has in some areas caused direct harm to certain wildlife species and indirectly affected others that prey on those who tend to accumulate residues in their tissue. Cacek (1985, as cited by Crosson and Ostrov, 1988) ties the estimated 40% to 80% decrease in wildlife population in the midwestern states from the mid-1950s to the mid-1970s in a large part to the increased use of agricultural chemicals. Legislation specially restricting agricultural chemical use in known habitats of endangered species has been enacted.

Increasing costs of production to farmers. The severe recession experienced by farmers in the first half of the 1980s has accentuated the need for cost-reducing technologies which provide less reliance on purchased farm inputs. For example, in California, costs of pesticide purchases and applications for speciality crops may be as much as 20% of total direct costs for a season. One California grower (Sills, 1988: 100) who has turned to organic farming reports: "it appeared to me that we were spending a lot of money to produce crops that were in over-supply, and using a great deal of high-priced chemicals to do so. In rice and almond weed control, it seemed that I was selecting for the weed that was hardest to kill, and invariably that last weed required the highest-priced herbicide to control it." Pest resistance to chemicals that have worked well in the past is an increasingly serious problem.

The U.S. Congress created and funded a new research and education program as part of the 1985 Food Security Act. Known as Low Input/Sustainable Agriculture (LISA), this program funds research and education activities that are intended to improve profitability of low-input farming alternatives.

Dwindling supplies of important resources. An energy crisis in the early 1970s and books and reports in the vein of *Limits of Growth* (Meadows et al., 1972) drew attention to the scarcity and capacity limits of important nonrenewable resources and their relationship to population growth and affluence. Lester R. Brown (1988) writes in *The Vulnerability of Oil-Based Farming* that "Agriculture is over the barrel. . . . The world-wide practice of boosting crop output by using more energy-intensive inputs will make agriculture more dependent on oil at a time when oil supplies are diminishing."

Recently, in the face of mounting commodity surpluses, U.S. farm legislation has taken a conservation posture. The 1985 Food and Security Act included provisions for a conservation reserve program, a conservation compliance requirement, and sodbuster and swampbuster programs; all aimed primarily at reducing soil erosion. The World Bank is also bringing environmental concerns to the center of its policy-making agenda with the creation of a new Environmental Department overseen by the vice-president of policy, planning, and research (AAAS, 1988). President Barber Conable said in his reorganization speech that "sound ecology is good economics."

What Do We Know about Sustainable or Low-Input Systems?

What do we know about alternative systems – ones that meet some criteria of sustainability or "regeneration"? Are alternative production systems ready for adoption in both developed and developing countries? The short answer is that the number of experimentally designed, empirically replicated studies on sustainable or low-input farming systems is very limited, compared to those on conventional methods. Ten years ago information was almost nonexistent.

The last few years show increasing evidence of research and extension activity dealing with various aspects of low-input systems in most every agricultural research institution (Madden, *in press*; Liebhardt, 1987; Poincelot, 1986; Reichelderfer, 1987). Many are comparative analyses, some using replicated experiments, whole farms, and side-by-side field comparisons. Farming practices in the eastern and midwestern United States have received the greatest attention nationally, with relatively little work done for specialty crops in the irrigated western states. An important point is that requirements for any farming system, including low-input, vary between countries, between regions, and even from farm to farm. Thus, much of the research so far on alternative farming systems is based on case studies that are only suggestive of possible outcomes but difficult to generalize.

Madden (*in press*) indicates that surveys of farmers and visits to farms where various low-input farming methods are used have provided insights regarding the profitability and potential for widespread adoption of these methods. Madden also stresses the need to consider the adoption of low-input techniques on a long-term basis to realize the full benefits. The complexity of tailoring a system to unique on-farm conditions requires time and considerable management skill.

Some of the alternative, low-input methods being analyzed include the use of natural enemies or biological control agents; appropriate field selection; changes in land preparation, irrigation, tillage, and sanitation practices; improved timing of planting; and choosing resistant varieties. Attempts are made to substitute renewable sources of soil nutrients such as manures and legumes for chemical fertilizers, partially or in total. Any of these changes must be considered in the context of the entire farming system. Case studies show that, under particular conditions, low-input systems can result in economic returns close or equal to what can be realized with conventional farming methods. In most cases, the farmer is substituting land, labor, and especially, management, for chemical inputs. The extra management/experience is emphasized by Madden (*in press*) who claims that if farmers choose (or are forced by regulatory or other pressures) to switch abruptly from chemical-intensive to certain kinds of low-input farming methods, initially their yields would probably decline sharply.

Studies of low-input methods often emphasize the cost/benefits of adopting a particular farming method as it relates to the enterprise (e.g., rotation effects on corn yield). Yet, proponents of sustainable systems contend that the effective "system" boundary usually includes the entire farm or management unit, its crop and animal mix, the crop rotation or sequence and the flow of materials through the system over time. Liebhardt (1986) points out that a systems analysis is required and that analysis must involve not only the inputs and outputs of the agricultural process, but the environment at large (physical, economic, institutional) and the interaction among these many components. Few studies are yet available that address such complex interrelationships on the whole farm for low-input practices.

Integrated pest management

Integrated pest management (IPM) is an approach that has achieved notable success in numerous regions and with a variety of crops – and falls within the rubric of low-input agriculture. The strategy is to use a combination of biological, physical, and chemical controls, habitat modification techniques, and "whatever works" to economically reduce pest damage and minimize chemical use. Programs have been developed for corn, cotton, alfalfa, soybeans, grapes, apples, almonds, peanuts, and tobacco, to mention a few. In many cases, farmers are able to reduce and sometimes eliminate pesticide applications that would be routinely used under conventional systems. And what is most important for widespread adoption, IPM practices are usually profitable, particularly when properly applied to cropping systems and regions where high rates of pesticides are normally used. As with other low-input practices, IPM calls for careful multidisciplinary analysis at the research level and more sophisticated and skilled management and more information at the farm level than is required for conventional or traditional farming.

A systems approach to research on alternative agriculture

Most proponents of low-input systems argue for orienting at least part of the research and extension activities around multidisciplinary teams who use a "systems approach." The whole-farm (and its environment) analysis requires the joint efforts of researchers and extension specialists in, for example, agronomy, soil and water sciences, entomology, animal science, engineering, and agricultural economics.

Table 2 illustrates the many factors – genetic, environmental, agronomic, and economic – which determine the specific types and amounts of pesticides needed for a particular crop, in a particular field, in a particular season. A multidisciplinary team effort and much individual consultation with users are required. Since most agricultural universities are organized around disciplinary departments and incentives within these departments are related mostly to individually published results within a specialty, considerable reorganization may be needed to mount a serious research/extension effort to understand and apply low-input agricultural systems.

Table 2. Factors influencing changes in pesticide use

Genetic	Environmental	Agronomic	Economic/Policy
Crop species Variety Pest resistance Chemical resistance	Location Climate Year-to-year changes Soil Water Pest populations and inoculum levels Beneficial organisms	Cropping pattern Planting date Irrigation methods Field selection Tillage	Management system on farm Consumer demand/ market structure Relative costs of control practices Regulations and farm programs Farmers beliefs and attitudes

SOURCE: Liebhardt (1988).

This is not to imply that all low-input methods and options require only applied research. The search for effective reduced chemical alternatives will require the full spectrum from basic to applied research. For example, developing strategies for using biotechnology against pests requires much basic research before application is even considered. Products from biotechnology approaching the marketing stage in two to seven years are improved microbial insecticides, pest-resistant transgenic plants, herbicide-resistant transgenic plants, insecticide-resistant transgenic parasites/ predators, transgenic bacteria, and production of natural antibiotic/antiviral agents by animals, plants, and bacteria (Hayenga, 1988).

Macro-effects of low-input systems: Research needed

While most attention has centered on the feasibility of low-input systems at the farm level, questions about the larger impacts on the economy (macro-effects) from widespread adoption of low-input technologies have been largely ignored by serious researchers. There is only one major study known to me. Langley et al. (1983) estimated aggregate supply and aggregate income effects for alternative scenarios comparing organic farming to conventional farming. Under the assumption that all farms would switch to organic methods, overall supply of soybeans, wheat , cotton, and feed grains would decrease, but the area farmed would increase. The value of production under the organic scenario would increase dramatically for all crops but soybeans, due to the restricted supply and an assumed inelastic demand. Higher costs of production would result due to inclusion of marginal lands in the production process, but net farm income would increase due to the higher value of production. The reduced supply under the organic scenario would mean a decrease of more than 50% in the level of exports below that in the conventional production scenario.

Numerous questions have been raised about the methods, assumptions, and data used in this study. Quite obviously, at this stage, so little is known about expected yields and costs for low-input systems for most U.S. cropping situations and the associated price effects, that its results must be viewed with caution. For one thing, new (even profitable) technologies are never adopted overnight, but require a considerable transition period. Therefore, more gradual adjustments in prices and resource use would be associated with any move toward low-input farming. So there is yet little guidance other than speculation about the important macro-effects (e.g., farm income, exports, consumer food prices, and the structure of the agricultural sector) of a switch in farming systems toward a low-input farming system.

Impediments to Change

Cochrane (1979) discusses how an entire technological strategy was forged for American agriculture based on cheap energy inputs (fuel, fertilizer, and pesticides) over the period 1920-70. The energy situation changed in the early 1970s, but investments (both in people and machines) consistent with cheap energy prices remain largely in place.

The farming structure that has evolved helps explain farmers' reluctance to adopt low-input or sustainable systems. For example, U.S. farms, as well as their counterparts in other developed countries, tend to be highly specialized. But multiple cropping systems and even multiple crop-livestock systems are the hallmark of most low-input systems. The fixity of the heavy investment in equipment and machinery (and debt load) of existing farms operating with conventional practices means that a formidable disinvestment would be involved in a switch to alternative farming systems. Also, most farm managers and much of the farm work force are trained for conventional agricultural system technologies; retraining has its costs and requires time.

Government programs that provide incentives for high-input farming were devised in an era of cheap energy and remain largely intact. The food processing and distribution system has evolved to complement the current production system and to meet the needs of masses of people in metropolitan areas. For example, the premium put on fruits and vegetables that are cosmetically appealing to consumers makes it difficult to produce and market profitably without chemicals.

Farming conditions and practices in a peasant agriculture would suggest an easy transition to low-input systems (Altieri and Anderson, 1986). Here, greater reliance is placed on family labor, integrated crop-livestock operations, and polyculture – all components of "sustainable" systems. Moreover, farmers in many developing regions are located on small holdings of marginal land with limited access to capital, credit, and markets, prerequisites for conventional agricultural operations. Yet, Reichelderfer (1987) observes that the trend is towards more, rather than less, use of agricultural chemicals in the developing world. Fertilizer application rates are up, with the largest gains in Asia whose rates doubled between 1974-76 and 1981-83; the value of pesticide imports to Asia more than tripled in constant dollars between 1971-73 and 1983-85. Apparently, in peasant farming areas using low-input practices that have evolved over generations, the pressure to boost food productivity via Green Revolution technologies and turn a profit means a shift toward the chemically intensive practices of the developed world.

An Agenda for Change

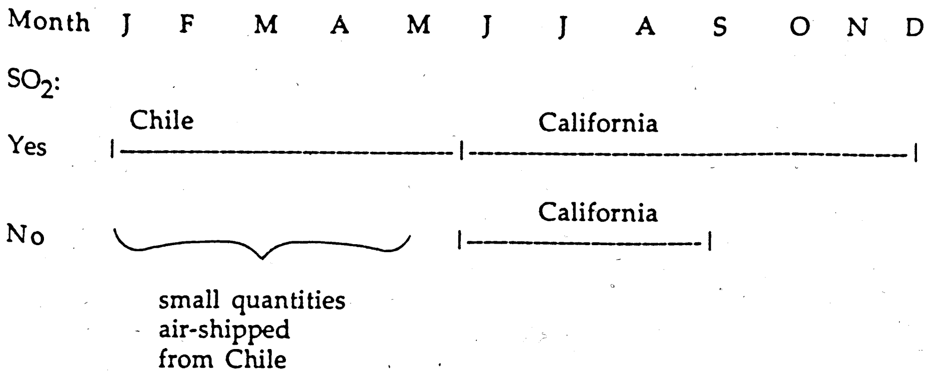
In conclusion, I make two observations. First, I would argue that our area of inquiry for considering change should be broader than the farm production system that has received so much emphasis. It is society and the people within it that we want to sustain over time. As important as the agricultural production system is to that goal, it should not be considered as an end in itself or independent of other aspects that come together to define quality of living in its broadest sense. It makes little sense to make decisions at the production level affecting the quality of the product if that product cannot be profitably marketed because of constraints in another part of the food chain. As agriculturalists, we must give primary attention to the total food system – production, processing, and distribution. That is, we want to consider changes in the total food system (and not just production) that can meet the growth in food demand and be consistent with societal long-run food safety and environmental goals.

Second, chemical use and any alternatives to chemical use at whatever level of the food system must be viewed and analyzed in a benefit/cost framework (even though some currently emphasize only the cost side, ignoring the benefits). And these costs and benefits are not only those to the farmers using chemicals, but to consumers and society as a whole.

Antle and Capalbo (1986) write of the benefits and costs to farmers and other food system participants and to society. Benefits to farmers from use of agricultural chemicals include increased yields and reduced pest damage; costs are the additional outlays for the chemicals and possible hazards in applying them. Similarly, benefits and costs can be calculated for whatever chemicals or additives are used at various levels of the food chain, including processors, wholesalers, and food retailers. Quantification of these costs/benefits for conventional practices is usually possible because of their impact through the marketplace; calculation of costs and benefits for low-input systems not yet in full operation is much more difficult.

Consumer benefits of chemical use within the food system include possibly increased quality and quantity of food and lower prices and increased availability of perishable foods over longer periods. Consider the health benefits of having a year-round supply of fruits and vegetables available in many parts of the world. Were SO_2 use eliminated from postharvest grape handling, the U.S. availability would shrink from year-round to just over two months (Figure 5). Costs to society may include consumer health risks from residues on crops, exposure of farm workers to contaminants, degradation of underground aquifers and waterways. Quantification of these effects is difficult since both market and nonmarket evaluations are involved.

Figure 5. Availability of table grapes in United States markets with and without SO_2 fumigation



SOURCE: Kader (1988).

Further, we need to understand what policies are appropriate when social benefits do not exceed or equal social costs. The impacts of any regulation usually extend far beyond its intended purpose. And conflicting regulations currently plague the food industry in the United States.

Increasingly, signals are being heard that our high-technology, energy-intensive agricultural system has not only *not* sustained agricultural and food productivity, but it is causing troublesome environmental problems and exerting pressure on the resource base. These concerns have not been translated into quick action and change. Legislation in the United States has been passed at the state and federal level aimed mainly at some of the environmental issues. Many farmers do express interest in changing to low-input practices, but so far they have not done so on a very widespread basis, for a variety of reasons – lack of knowledge, risk of decreased profits, or fixity in existing investments. Farmers can't be expected to bear all the costs when they can claim only a share of the perceived environmental benefits.

Agricultural academic institutions are allocating only a small percentage of their budgets to sustainability or low-input research projects but this is several-fold more than it was even five years ago. Biotechnology is the current "favorite" in many land-grant institutions and is taking a lion's share of the budget. The U.S. Department of Agriculture is funding a relatively small program of research and education on low-input sustainable agriculture but this is infinitely more than it has been in the past. My impression is that the level of activity is similar in other countries.

In summary, we have considerable interest – even deep concern by some groups – but no groundswell of support for abrupt action or change. Nor do we have sufficient information on the farm, regional, or global impact of such a change. The current agricultural system evolved over considerable time, and with some "nudging and pulling" we can in time tilt it in a different trajectory. As Douglas (1985) stated earlier – as research scientists, we must try harder to anticipate and minimize the adverse consequences of potential new technologies and designs. The general public must continue to articulate its concerns and our representatives in government must respond to them.

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