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SUSTAINABLE AGRICULTURAL SYSTEMS

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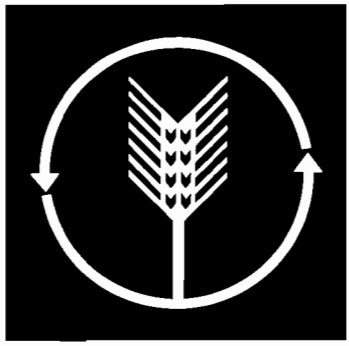

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FOREWORD

Early in my married life, I went to India as a staff assistant to the American ambassador for four years. It was there I came to appreciate the degree to which agriculture really is the cornerstone of the economic health and well-being of any country. To live in India from 1963 to 1967, which as many of you know were critical years in the emergence of the green revolution in that country, was a most exciting time. I worked with an ambassador named Chester Bowles, who was a great believer that agriculture came before industrial development. He regularly debated that proposition with Prime Minister Nehru and appealed to a book of ancient wisdom in India that began, "Agriculture is the lynchpin of the social chariot."

From a local standpoint, Ohio is part of those midwestern states that comprise about a quarter of our nation's population, but provide four out of ten of the farmers in our nation. These farmers produce more than 44 percent of our nation's food products. Here in Ohio, which is often thought of as an industrial state, and it is, agriculture, in terms of food production, processing, and marketing, is the state's number one industry. In 1988, we faced the worst drought in many years, perhaps on record, and it has reminded us of just how fragile our hold on this agricultural wealth is.

The history of agriculture in the 20th century is a story of dramatic technological advances that have led to increased production. Indeed, I've often thought that the manufacturing industry could learn a great deal from agriculture about how to increase productivity.

Still, without the recent rainfall, I believe this country would have faced a disaster of unmatched proportions despite all of the advanced technology available to us. The impact of such a disaster on American farmers and

consumers would, of course, have been harsh, but it would have been catastrophic for millions of people around the world whose survival still depends on repeated bumper crops of American agricultural products.

Just as the Midwest is the nation's breadbasket, it has, in many respects, been the world's breadbasket. And while we're proud of that fact, I think we ought also to be humbled by that responsibility and to recognize that it is something that needs to change over time. All of this perspective gives, I think, additional meaning to the concept of sustainable agriculture. To me the word "sustainable" has several important aspects, not the least of which implies the future. When we talk about sustainable agriculture, we talk not only about low inputs for optimum production, we are also talk about agriculture with a future, agriculture with a dependable future.

The experience of our last few months here in Ohio and in this part of our country also reminds us of how indivisible we are as a human family. Two years ago, Ohio farmers provided relief for their counterparts in the southeastern United States as they were reeling from a drought there. Many of those farmers had the opportunity to return the favor this year. Ohio farmers were struck by the fact that as we worried about the drought in our own state, our sister province in China, Hubei Province, suffered a similarly severe drought. Our farmers commented on the irony that here we were, sister state and sister province, both confronted by a similar challenge to our agricultural abundance.

The fact is that we live in an increasingly integrated global economy where virtually everything is interconnected, and the days are long since past when we could refer to the U.S. economy as a free-standing entity. In this, the year the earth talked back, we have also begun to understand that we live in a single ecosystem where the greenhouse effect, the destruction of the ozone layer, the impact of acid rain, the consequences of deforestation are shared by all, and make the prospects of sustainable growth the greatest challenge before us. This is not an American problem or a Third World problem. This is a worldwide challenge that we all must begin to meet, and we must meet it as much here in America's heartland as in any other part of the globe.

Richard F. Celeste

PREFACE

Modern agriculture in developed countries currently depend upon high inputs of inorganic fertilizers and synthetic chemicals for pest control and tends towards monoculture of cash crop varieties that require such inputs. These practices have increased overall productivity, but they have also led to overproduction of certain crops in the United States and Europe, which has reduced farmers' profit margins because of the inevitable drop in market prices of crops. Intensive production also has the potential to accelerate wind and water erosion of soils and to result in the contamination of surface water and groundwater.

There is a growing awareness about the need to adopt more sustainable and integrated systems of agricultural production that depend less on chemical and other energy-based inputs. Such systems can often maintain yields, lower the cost of inputs, increase farm profits, and reduce ecological problems. Some developing countries, having used subsistence agricultural practices and subsequently increased yields by adopting higher input methods, are now experiencing greater pest, disease, and weed problems; increased soil erosion; environmental hazards; and economic stress. Yet the need to increase food production in these countries is greater than ever before. Hence, there is an urgent need for both research and education on sustainable farming systems that can increase productivity and profits for farmers without endangering the resource base and polluting the environment.

This same situation exists throughout the world. In the United States, the Department of Agriculture (USDA) made significant new funds available to promote sustainable agriculture in 1988. These funds are expected to

remain available and perhaps even increase in the years ahead. The governments of most European countries likewise are paying increased attention to the need for lowering chemical inputs to avoid environmental problems, and these same countries are reviewing means of reducing production overall. There are also major programs in the U.S. Agency for International Development, the World Bank, and the World Resources Institute aimed at promoting the concept of sustainability into the 21st century in Third World countries.

This circumstance, worldwide, makes these proceedings of the International Conference on Sustainable Agricultural Systems that was held at Ohio State University, Columbus, Ohio, in September 1988, and jointly organized by Ohio State University, Pennsylvania State University, and North Carolina State University, extremely timely. The conference was made possible by the generous sponsorship of USAID and three USDA agencies, the Cooperative States Research Service, the Soil Conservation Service, and the Agricultural Research Service, along with the Rodale Institute and the Farm Foundation. We are also grateful to the Soil and Water Conservation Society for the prompt publication of this material.

The conference included 38 formal presentations, which form the contents of this book, and 40 poster presentations, some of which are being published elsewhere. There were also five workshops that addressed critical issues on (1) "Government Policies and Strategies to Promote Sustainable Agriculture," (2) "Innovative Technical Assistance and U.S. Aid Policies to Promote Sustainable Agriculture in Developing Countries," (3) "Research Education and Extension Strategies in Sustainable Agriculture," (4) "The Agrochemical Industry in Relation to Sustainable Agriculture," and (5) "Building on Success: Farmer Participation in Sustainable Agriculture." There was one informal discussion group as well on the "Role of Women in Sustainable Agriculture." Participants in each of these sessions were asked to discuss present policies and strategies and develop recommendations on future research, teaching, and extension activities. The discussion in each case was summarized by a rapporteur and presented to a plenary session of the entire conference for comment and discussion. The conclusions have since been published as a booklet by the Rodale Institute.

Clive A. Edwards

INTRODUCTION

The topic of agricultural sustainability is a high priority in all countries around the earth, whether they are developed or developing in their current economies. Some would say it has been too long in receiving attention. But I prefer to view it as timely and relevant.

There is no more important question before us on this globe today than that of the sustainability of agricultural systems. Desertification, deforestation, and accumulation of chemicals in soils and waters are of increasing concern in many ecosystems and different parts of the world. One can find a growing number of such citations in both scientific and popular publications, to the degree that not only scientists but also the general public are raising serious questions about the current state of affairs and potential alternatives for the future.

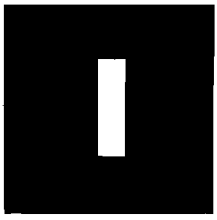
It has been authentically reported that some agricultural systems that were once popular have disappeared over time because they could not be sustained for a variety of reasons. Others have been sustained for thousands of years and are still flourishing. Not enough has been done to analyze the differences between those systems and practices that persisted and those that did not. Such analyses might provide insight concerning the present and future.

Many definitions of the term "sustainable agriculture" have been presented, and that is as it should be. We must recognize the varied points of view that enter such a discussion. For me the term sustainable merely adds a long-term dimension to consideration of any agricultural system. It requires studies that are conducted over a long period of time, such as decades, rather than for three or four years. I might point out the Rotham-

stead plots in England and the Morrow, Jordan, and Sanborn plots in the United States are excellent examples of long-term experiments that have contributed invaluable information. I am convinced that we must initiate new studies with a long time frame that integrate many of the current and innovative farming practices in a variety of ecosystems.

Much has been written recently regarding the environmental and the economic aspects of sustainable agricultural systems. A sustainable system must be both economically profitable and environmentally compatible. As William Ruckelshaus has pointed out, "Unlike railroad tracks, economic development and environmental protection really do converge if you take a long enough view."

F. E. Hutchinson



AN OVERVIEW OF SUSTAINABLE AGRICULTURE

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A HISTORY OF SUSTAINABLE AGRICULTURE

Richard R. Harwood

To provide a conceptual setting for the definition of sustainable agriculture and to show evolutionary trends in its development, two reference points in that evolution are of special importance. These two reference points are not meant to be exclusive but rather to represent a spectrum of thought.

The first reference point should be placed in the early 1980s, with the emergence of the concepts of regenerative agriculture (Rodale, 1983) and the articulation of a sustainable agriculture (Jackson, 1980). The early concept has evolved into a construct of agriculture based on principles of ecological interaction. It is referred to as an ecological definition of sustainability. This concept now forms the philosophical basis for most alternative agricultural groups.

A second reference point is the increased use of the term sustainable, starting in 1987, to refer to a "stable" agriculture in the global sense, involving all facets of agriculture and its interaction with society. It is the "universal" sense that seems to be the object of this book.

A Framework for Universal Definition

The word sustainable implies steady state. If one sees a steady-state situation, one must look over horizons to some distant goal. A careful reading of development literature reveals as many ideas about direction as there are authors, so consensus on an equilibrium point would be impossible. Lack of understanding; of hard data; or of consensus on resource bases, global climate and its variation, technologies of the future, the role of peo-

ple in agriculture, and the relationship between people, agriculture, and the environment all make prediction of an end point a futile exercise. Others could argue as well that there may never be an end point or equilibrium but, as with the rest of the universe, a continual process of evolution.

Given the limits of vision, of data, and of the imprecision of a process for arriving at consensus, I suggest using a "framework" definition that can be filled with appropriate detail by country and by desired time frame. A workable definition is *"an agriculture that can evolve indefinitely toward greater human utility, greater efficiency of resource use, and a balance with the environment that is favorable both to humans and to most other species."*

This definition is heavily value-laden, but it is consistent with the parameters of an emerging social and political agenda for agricultural development. It is also very much generic. To understand the process by which it is translated into substance in any national setting, some sense is needed of public agendas, the translation of those agendas into policy, and the roles of agendas and policy in development.

Evolution of the Sustainability Concept

Agricultural evolution always has been guided by a perception of what should be, sometimes called the model, the goal, or even the ideology. The difference between that goal and agriculture as it exists presently is the development gap. The breadth or all-inclusiveness of the model likewise changes with time. We could analyze at great length the philosophical bases for development, but we will limit ourselves to just a few key concepts that seem most closely related to present sustainability concepts.

Some analysts take us back to origins of current conflict in a Newtonian world view. Rifkin (1980) characteristizes that view by four relevant elements: a mechanical view of nature, a rigid dichotomy between nature and society, a faith in progress, and a consumerist ethic. Others point to the 17th century English philosopher John Locke who wrote on the social goal of efficiency in agriculture by stating, "He that encloses land, and has a greater plenty of the conveniences of life from 10 acres, then he could have from a 100 left to nature, may truly be said to give 90 acres to mankind." Others point to Thomas Jefferson's linkage of agricultural practices with morality. In notes on the State of Virginia in the late 1700s, Jefferson (1984) wrote, "Those who labor in the earth are the chosen people of God, if ever he had a chosen people, whose breasts he has made his peculiar deposit for substantial and genuine virtue. . . ." Corruption of morals in the mass of cultivators is a phenomenon of which no age or nation has furnished

an example. The poet and philosopher Emerson expressed a similar belief. Some would say that the thoughts of Newton are reflected closely in the global view of the Battelle Institute (1985) and those of both Jefferson and Emerson in the works of Wendell Berry (1978). Certainly, the conflicts now faced in the articulation of a universal paradigm are in many instances the same as those addressed by writers of two centuries ago.

However, we are not as concerned here with philosophical content as much as with process. At the turn of the 20th century, U.S. agriculture was in the early stages of industrialization. The conflict between an urban "agrarian" lifestyle and what were seen as radical changes being brought on by industrialization was already present (Danborn, 1979). More important, however, were the divisions among and between farmers and the growing community of "land-grant" scientists. Now these divisions have returned to haunt us 80 years later.

In the early 1900s, popular thinking among farmers had led to rejection of the portion of Jeffersonian thought that held individualism to be supreme. Politically, this led to establishment of organizations, such as the Grange. Farmers felt that they should develop and share technological knowledge among themselves. There were two sources of that knowledge. The "systematic agriculturists" looked to the emerging industry as their model. The second group, the "scientific agriculturists," looked to nature as their model, with the objective of rationalizing and formalizing their experiences as "natural historians" (Marcus, 1985). At the same time, land-grant scientists were beginning to have an impact (Rossiter, 1975). It is these philosophies and to these turn-of-the-century farmer-scientist groups that we can trace the roots of much of the current debate on sustainable agriculture.

U.S. agriculture was in a major expansionist mode during the early 1900s. The number of farms reached a peak of 6.8 million in the early 1930s (Hardin, 1988). Mechanization was being adopted rapidly, spurred by rising costs and the scarcity of labor brought on both by area expansion and by competing demands for industry. Technologies were increasing rapidly, as exemplified by the development and widespread adoption of crop hybrids. The land-grant system was a major determinant in the articulation of the development paradigm. During the early 20th century, the concepts of conservation evolved, first giving emphasis to preservation of natural areas. The progressive conservation movement of the early 1900s established the intellectual foundations of the later conservation programs (Batie et al., 1985).

A series of conservative programs reflects these common roots, including the Agricultural Adjustment Act of 1933, the Soil Bank Program of 1956, and the Food Security Act of 1985 (Phipps and Crosson, 1986). These pro-

grams addressed both the problems of soil conservation and of growing surplus production through the mechanism of land reserves or set-aside acres (Hardin, 1988; Jeske, 1981). Parallel to these developments and to the spread of new crop technologies and to rapidly expanding mechanization was the spread of "chemical" technologies. The use of industrially produced fertilizers spread rapidly after World War II, and that of pesticide development followed close behind, leading to what Rifkin calls "the age of alchemy" (Rifkin, 1983).

I would like momentarily, however, to review a thought development process of major significance to the concept of sustainability that traces its origin through Malcolms' "scientific agriculturists." At the turn of the 20th century, the concepts of wholism versus reductionism were taking shape (Harwood, 1983). The emergence of thought on wholism, of looking to natural systems as a model, and of the role of farmers in evolving their own systems (all concepts mentioned above) led to what is today generally referred to as "alternative agriculture." Alternative agriculture evolved during the 1900s in a course parallel to that of industrial agriculture, borrowing liberally but selectively from technologies, such as new crop varieties, mechanization, and soil nutrient testing. A review of that evolution helps greatly to understand today's debate. Many of today's alternative agriculturists trace their history back, surprisingly enough, to Darwin.

Charles Darwin spent his later years in England meticulously studying soil floral and faunal activity. His extremely interesting work, *The Formation of Vegetable Mold Through the Action of Worms, With Observations of Their Habits,* documents in great detail the intricate biological balances in the soil (Darwin, 1882).

In the early 1900s, several works focused on the broader, nonsimplistic aspects of agriculture and their complex interrelationships. Elliot (1907) wrote of the complexities of pasture mixes and their importance to soil fertility in rotations. The true classic, however, which stimulated later thinkers of the British and American schools, was King's *Farmers of Forty Centuries* (1911). King described in this book and in his following book, *Soil Management* (King, 1914), the complexity of integration in the then highly productive, traditional systems of Asia. The interrelationships between these systems were the key to the thinking of all agriculturists who followed.

Biodynamic Agriculture

The first organized and well-defined movement of growers and philosophies was the biodynamic movement, which arose from a series of lectures given by Rudolf Steiner, the founder of anthroposophy, in 1924 (Steiner,

1958). The basic tenets of biodynamic farming include:

- Sound farming and gardening techniques, no matter whether old or new.
- Such principles as diversification, recycling, avoiding chemicals, decentralized production and distribution, etc.—ideas held in other biological movements. Since the 1920s, biodynamic farmers have developed the execution of such principles and also reintroduced useful traditional techniques.
- The specific biodynamic measures and concepts as they evolve from Steiner's spiritual teaching, which mold the method into a consistent whole (Koepf et al., 1976).

The latter point is usually what separates biodynamic practices from the rest of biological agriculture. It includes "the stimulation and regulation of complex life processes by biodynamic preparations for soils, plants, manures" (Koepf et al., 1976). It also includes the consideration of cosmic and terrestrial forces on biological organisms. Biological rhythms are affected by a range of cosmic forces. Although growing evidence, mostly from biomedical research, suggests the occurrence of such effects, their importance in agriculture has not been evaluated.

Early writers on biodynamic agriculture include Pfeiffer (1934, 1943, 1956) and Baker (1940). These publications set forth the arguments for the disruptive effects of concentrated synthetic fertilizer and pesticides, which have been major aims of all biological or organic practitioners through the years. The connections between the biological "health" of the soil and the health of animals and humans associated with it, or using produce from it, were also articulated at this time.

All of these concepts did not originate with the biodynamic school, but they became an integral part of the thinking of Steiner and his followers. More recent summaries of the biodynamic concepts include Koepf (1981), Steiner (1958), Rateaver and Rateaver (1973), Pauli (1967), Koepf et al. (1976), Pank (1976), and Jeavons (1979). Although the biodynamic movement is concentrated in European and Scandinavian countries, a limited number of practitioners, both commercial and home-garden, are found in the United States and Canada.

Development of "Humus Farming" Concepts

A school of thought evolved both as a part of and in addition to the biodynamic school that focused on the importance of humus in agriculture. This concept provided the foundation for several philosophies of biological agriculture that emerged from the 1930s through the 1960s.

Browne, in 1855, wrote *The Field Book of Manures or the American Muck*

Book. Roberts (1907), Fletcher (1907), and Waksman (1936) wrote basic works on humus-oriented soil fertility that, at the time, were considered states-of-the-art in scientific thought.

A major development that not only advanced techniques of compost-making but began to discuss the disruptive effects of concentrated synthetic fertilizers was that of Howard and Wad (1931). This work marked a major point of departure for the humus-farming school. Publication of definitive technical books and applied humus-farming books soon followed (Billington, 1942; Bruce, 1943, 1945a, 1945b; King, 1943; Waksman, 1936).

In 1943, Sir Albert Howard's book, *An Agricultural Testament,* became a new landmark. Not only did it add significantly to the emerging thought on humus farming through its exposition of the Indore method of composting, it restated in positive, modern terms the concept of integrated farming. *An Agricultural Testament* influenced the Soil Society work in England as well as the writing of J. I. Rodale in the United States. Subsequent works by Howard elucidated further the connections between soil and health and clarified the methods to be used in an agriculture based on biological structure rather than on the use of synthetic chemical inputs (Howard, 1945, 1946, 1947).

The humus-farming philosophy reached its peak in the early 1950s with publications by Sykes (1949, 1952, 1959) and Seifert (1952). These works proved to be the mainstay of the organic farming movement that followed. The principles of composting and compost use were well articulated by this time, and considerable research has since been done on the handling of municipal waste, with emphasis on methodologies. Many feel the culmination of agricultural composting studies is the *Rodale Guide to Composting* (Minnich and Hunt, 1979).

Emergence of the Organic Philosophy

The basic tenets that led to organic, biological, and ecological agriculture and eventually to the regenerative farming movement can be traced to Sir Albert Howard's *An Agricultural Testament* (1943). The ideas of an integrated, decentralized, chemical-free agriculture were advocated by Northburn (1940) in a largely overlooked work. As far as we can tell, he was the first to use the word organic to refer to the entire philosophy and practice.

Graham (1941) and Barlow (1942) exemplified the rethinking of agricultural practices that occurred in the 1940s. Barlow was especially critical of the impacts of agriculture in the early 1940s on soil degradation and reduction in diversity through specialization. The momentum increased signifi-

cantly with the publication of Lady Eve Balfour's *The Living Soil* (1943). Faulkner's *Plowman's Folly* (1943) was another classic, spurred by the Dust Bowl of the 1930s in the American Great Plains. Faulkner described in forceful terms the biological and human tragedy resulting from misdirected technology. In 1945, J. I. Rodale's *Pay Dirt* became a rallying point that carried the organic movement in America through the difficult 1960s. A lengthy series of books by J. I. Rodale was to follow (1948, 1953, 1954, 1977).

The late 1940s and early 1950s were prolific periods for organic literature. Faulkner (1946, 1947, 1952) was not only a critic of contemporary agriculture but an experienced extension agent and farmer as well. He detailed his own experiences in the regeneration of worn-out soil with organic farming practices.

Louis Bromfield also contributed significantly with his accounts of organic farms on which people, crops, and livestock were intermeshed in a living system (Bromfield, 1946, 1947, 1950, 1955). Bromfield felt strongly that the sensitivity, skill, and dedication required of a good farmer meant that "not everybody can farm" (1950). Several other authors, including Pfeiffer (1947), Cocannouer (1950, 1954, 1958), Hainsworth (1954), Howard (1947), and Widkenden (1949), continued through 1956 to articulate the increasing environmental harm and resource degradation brought about by "modern" farming methods. They repeatedly advocated the holistic approach to agriculture.

As with the earlier notions of Newton, Locke (1980), and Emerson (1904), many of the issues debated and the relationships suggested during the first half of the 20th century have become focal points for discussion in today's debate on sustainability. The concepts of wholeness, of an ecological model, of a fragile relationship with the environment, and a host of farming practices are being reconsidered.

The 1960s: A Transition Period of Narrow Focus

By the late 1950s, the evolution and spread of industrial technologies had increased exponentially. In the developed nations, the industrial model was widespread. Moves toward crop specialization on the farm, permitted by the availability and low price of fertilizers and pesticides, had accelerated. The increased need for power as farmers grew only one or two crops was met by larger horsepower tractors.

Capital for investment was readily available, perhaps generated in large part by undervalued energy costs. The major problems were agricultural surpluses. For those of us who went through our graduate training in agriculture during the early 1960s, it was a time of scientific euphoria. We

were in the post-Sputnik era and very literally on our way to the moon. As scientists, we considered that we were masters of our fate and the fate of humankind. Our technologies and our opinions, spoken from the dias of science and academia, dominated the formulation of the development paradigm of the day. Gone were the traditions of humus farming, of mechanical weed control, and of the need for large portions of our population to be involved in agriculture. Farming was now a business, to be run as efficiently as any other industrial enterprise. Soil conservation seemed to be the only major theme from past decades that remained in the model. We gave it major attention and resources, but our focus was on correction of the problems caused by crop technologies, not on prevention of them. We focused on terraces, levees, and farm ponds to slow and stop the runoff from the bare-soil corn and soybean fields. We were structuring our farms and our technologies according to valid Newtonian principles, applied with full intentions to dominate the earth.

There was little or no debate during those years, in the biological sciences at least, on development direction. The success of current technologies was so overwhelming that it stifled serious debate of alternatives. The alternative farming "schools" were practically nonexistent and certainly in disrepute. I remember clearly graduate school discussions in 1964 about the "crackpot Rachel Carson and her whistling in the wind" against the great benefits of DDT. In looking back on those heady years, I wonder about our arrogance and narrowness of vision. I also wonder, parenthetically, if many of us still remain intellectually in the comfortable era of the early 1960s when we trained. But the results of the narrow focus were far from being entirely negative. The concentration of scientific and development resources during the late 1960s and early 1970s achieved dramatic results.

The Green Revolution

Agricultural development trends and breakthroughs up to and including the Green Revolution are interestingly summarized by Dahlberg (1979). He gives heavy emphasis to the emerging influence of the foundations and to international development assistance during the 1960s and 1970s as determining the development paradigm of the era. Those working in international development at the time followed the "commandments" according to Moser (1969):

- Research to find and develop new and improved farm (and related) technologies.
- Arranging for the importation and/or domestic production of farm supplies and equipment needed to put the new technology into use.

- Creating a progressive rural structure, or "organization of the countryside," that provides channels through which goods and information can move easily back and forth between each farm and the total society in which it is located.
- Creating and maintaining adequate incentives for farmers to increase production.
- Improving agricultural land.
- Educating and training technicians to accomplish all of these tasks competently.

In the process, the extension agent was seen as the "advisor, teacher, analyzer, and organizer" (Moser, 1969).

That the approach had significant impact is without question. In spite of massive and unprecedented increases in population since the 1950s and in the face of predictions of (and actual instances of) starvation in Asia, country after country, including India, Bangladesh, China, the Phillippines, Indonesia, and many others, have achieved food self-sufficiency and even food surpluses. The approach has worked best, however, in areas with good soil and water resources where returns to infrastructure development, to technology application, and to inputs have been high. Farm size, interestingly, has not been a factor in responsiveness where population density is high and where agriculture remains the predominant employer. In Asia, at least, mechanization has played only a modest role, limited to a few key technological areas. This latter distinction is significant because it plays a major role in the definition of sustainable agriculture for many, if not most, Third World countries. Those national definitions are now focused on many of the shortcomings of the Green Revolution model: the problems of equity, of rural income, of product diversity, of environmental impact, and of huge neglected areas of poor soil and water resources that must support increasing numbers of people.

Broadening the Profile for Sustainability

In the late 1960s and early 1970s, several trends or events occurred to spur agricultural development and thinking beyond the new boundaries of the early 1960s' model. The increasing awareness of the impact of modern (industrial) technologies on the environment became clear as we traced pesticides in our food chains. Crop nutrients began to accumulate in streams and in underground aquifiers. Water resources became oversubscribed, and the "spaceship earth" concept was born. An event that shook our consciousness, however, was the energy "shortage" of the early 1970s. For the first time, we became painfully aware that earth's resources were limited.

The analysis by Hill and Cleveland (1981) of the energy cost of exploration and of recovery of oil and gas was reported by Gever et al. (1986):

"In the 1950s, we discovered about 50 barrels of oil for every barrel invested in drilling and pumping. Today, the figure is only five for one. Sometime between 1994 and 2005 that figure will become one for one. In other words, perhaps as early as 1994, it will generally become uneconomical to search for any oil for energy in the United States."

While certainly not everyone shares this view of the short time frame involved, there is little question that business as usual should be questioned. For these and for a broad range of other reasons, agricultural development directions have come under serious debate and analysis. The university-based scientific communities have been joined by a plethora of private "think-tank" and industrial groups all making contributions.

From the alternative agriculture point of view, several scenarios for sustainable agriculture have been articulated. Most include principles evolved during the early 1900s and stress the following (Harwood, 1983):

- The interrelatedness of all parts of a farming system, including the farmer and his family.
- The importance of the many biological balances in the system.
- The need to maximize desired biological relationships in the system and to minimize use of material and practices that disrupt those relationships.

The several modern articulations of world views of "alternative agriculture" include but are not limited to Berry's *The Unsettling of America* (1988) (stressing the importance of human participation from a morality standpoint reminiscent of Jefferson), Walters' *The Case for Eco-Agriculture* (1975), Rodale's *Breaking New Ground* (1983), and Jackson's *New Roots for Agriculture* (1980). These authors all derived their thinking from the alternative agriculture tradition, but they differ markedly in their approaches.

Closely associated with these works are those of the agroecology movement, best known by scientists through the work of Altierri (1987). These authors combine the scientific method of modern ecology with the older concept of the scientific agriculturists of learning from nature. Although the idea seems romantic, it has evolved in an age of realism. Quinney of New Alchemy wrote: "Today, although we have a better understanding of the limits of this concept, nature as inspiration is still powerful and increasingly useful" (Quinney, 1987). Perhaps the most eloquent of these works is Dover and Talbot's *To Feed the Earth: Agro-Ecology for Sustainable Development* (1987).

For those who would attempt to articulate any national sustainable agriculture paradigm, there are several other key readings: *Farmland or Wasteland: A Time to Choose* (Sampson, 1981); *Paying the Price: Pesticide Sub-*

sidies in Developing Countries (Repetto, 1985); *Defusing the Toxic Threat* (Postel, 1987); *Ecological Aspects of Development in the Humid Tropics* (National Academy of Science, 1982); *State of the World: A Worldwatch Institute Report on Progress Toward a Sustainable Society* (Brown et al., 1986); *Crop Productivity: Research Imperatives Revisited* (Gibbs and Carlson, 1985); and *Agriculture 2000: A Look at the Future* (Battelle Memorial Institute, Columbia Division, 1985).

National Agendas for Agricultural Development

A public agenda is an accumulation of issues that attract debate and concern. The contributors include individuals, social groups, institutions, government agencies, and power brokers. Issues achieve agenda status when they receive widespread and continuing public recognition. Public agenda items then receive policy status when they receive sanction in the form of law, funding, or other official pronouncement or action. Present U.S. agricultural development agenda items can be grouped into the following five categories (with examples of frequently heard, specific concerns):

- *Increase the utility of agriculture.* Maintain adequate production. Provide adequate livelihood (considering equity, stability, safety, lifestyle) for a desired number of participants. Provide food of acceptable quality and diversity (no pesticides, low heavy metals, little fat, good flavor, little processing, few preservatives, no antibiotics, regulated levels of synthetic hormones).
- *Increase productivity.* Develop more productive biotypes (with pest resistance, tolerance to adverse conditions). Maintain soil organic matter, tilth. Maintain crop diversity. Practice rotations. Use integrated animal/fish/crop/tree systems. Practice nutrient cycling.
- *Maintain an environment favorable to humans and most of other species.* Protect groundwater from contamination. Reduce or eliminate use of pesticides. Reduce use of synthetic fertilizers. Encourage wildlife maintenance. Recognize animal rights (reduce stress in confinement, provide for a degree of natural activity).
- *Assure the ability to evolve indefinitely.* Minimize soil loss (from erosion, conversion to nonagricultural use). Stop overdraft of fossil groundwater. Reduce energy use (especially of fossil fuels). Develop better technologies for biological nitrogen fixation. Develop perennial cereals. Maintain existing genetic diversity.
- *Develop patterns of geographical distribution and scale (macro structure) consistent with national agendas.* Create adequate physical and institutional infrastructure. Develop market channels that respond to market

and social needs. Manage corporate activities that may control portions of the agricultural sector. Monitor (or manage) land ownership (land is usually considered to be a quasi-public resource).

Recognition of these points is given or implied in the above definition of sustainable agriculture. Most of the five categories are recognized in a current definition (TAC, 1988): Sustainable agriculture should involve the successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the natural resource base and avoiding environmental degradation.

The U.S. Agency for International Development (1987) avoids a specific definition but identifies a long list of parameters that fall into the five suggested categories.

These five categories are purposefully broad to include most possible items. The breadth is the result of historical process, as we shall see below. In most countries where debate is prevalent, the concerns are remarkably similar to those in the United States. The priorities change with resource base, stage of agricultural d velopment, and national politics. The consistency and speed with which particular items reach policy status depends upon the size and influence of the proponent group, the perceived seriousness of the problem, and government responsiveness. Those relationships are little understood, even here in the United States. They are influenced to some extent by prominent events, such as pesticide spills, farm bankruptcies, or major disasters.

The public agenda must be both nation- and time-specific. Its establishment is a people-driven process that differs from country to country. A process of goal-setting, of identifying gaps between existing and desired future states, and, finally, of priority setting and resource allocation completes the process. In most countries, neither farmers nor agricultural scientists are the sole or even the major determinants of what is sustainable. Their roles in technology development are probably their most significant contribution.

From Concept to Action

Our concept of the multiple dimensions of a sustainable agriculture is more broad today than at any time in history. We are more aware of the potency of technologies, of the fragility of the earth's environment, and of humankind's ability to disrupt it. We have a notion of earth's limited resources. This is appropriate at the threshold of our transition from the age of alchemy to the age of biotechnology.

As we survey our past, it seems that consensus is possible on three ma-

jor points: (l) Agriculture must be increasingly productive and efficient in resource use, (2) biological processes within agricultural systems must be much more controlled from within (rather than by external inputs of pesticides), and (3) nutrient cycles within the farm must be much more closed.

A less well-recognized point is that crop nutrients must come from management of nutrient flow into and out of the soil organic matter fraction, a "farming of the organic matter" rather than a "farming of the soil nutrient solution." There is ample circumstantial evidence from alternative agriculture on this point but, as yet, little scientific evidence. If we are to learn one central lesson from all of alternative agriculture, I think it would be this one.

We may dev('op the sustainable model for the United States, but how do we approach sustainable Third World development? No Third World country has so broad a public agenda for development as do the western developed nations, nor do they have such a plethora of well-funded public and private agencies that are contributing to that agenda. Do we take our own agenda with us when we go to the tropics? Certainly, we must not ignore the differences in priorities, which is a primary emphasis in Asia, on rural income and employment as opposed to our own priorities. We must see the drain of wealth from rural areas as a result of inappropriate structure of the agricultural system. But should we impose our own priorities of food safety, of environmental impact, or of human safety in agriculture on developing countries? We have no ready answers, but we must be sensitive and responsive to national agendas in each country in which we work. We must choose our attack points carefully, remembering that progress is most rapid when effort and resources are focused best.

But how about our own agenda for sustainability? As scientists, how do we react to the realization that we no longer dominate the agenda-setting process for agriculture. Do we understand the impact of all five areas of a sustainable profile? If you are a land-grant scientist, how do you relate? The words of Sandra Batie, in my opinion, are wise counsel: "The new agendas of a concerned public should be seen neither as a threat nor as irrelevant to the land-grant tradition but as challenges and opportunities to better serve the needs of society. Land-grant colleges of agriculture must embrace opportunities to assist in identifying and designing solutions which are in our finest tradition of being the 'people's' university" (Batie, 1988).

As we survey the past and then move ahead to determine our future, we should cherish the diversity of thought and experience that provides the "raw material" for evolution of a new paradigm. The implementation

of that new model requires new attitudes, new policies, and new technologies.

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