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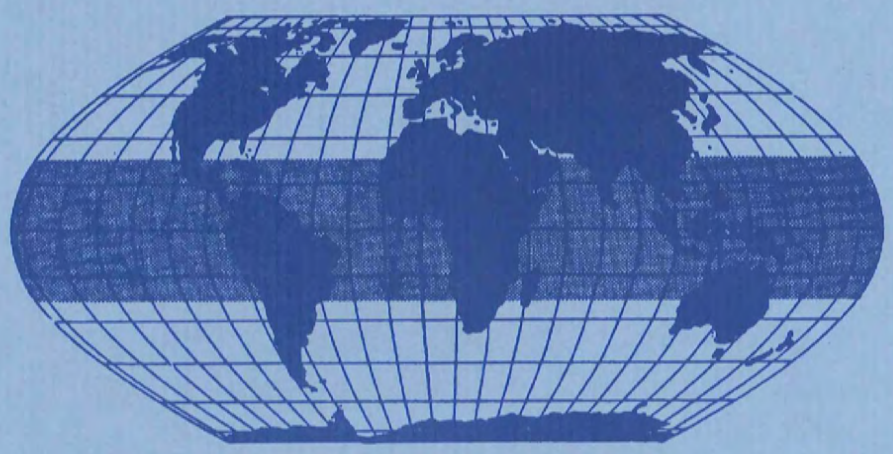
Sustainable Agriculture is the Solution, but What is the Problem?



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SUSTAINABLE AGRICULTURE IS THE SOLUTION, BUT WHAT IS THE PROBLEM?

-by-

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Preface

Population growth and environmental quality are moving in opposite directions. To avoid catastrophe, soil, water, air, genetic and energy resources must be managed, not only to produce more, but to produce on a sustained basis. The alternative is the loss of population-supporting capacity for man and beast and a general decrease in the quality of life for all living things.

The Board for International Food and Agricultural Development and Economic Cooperation (BIFADEC) was among the first agricultural groups to hear the environmentalists and conclude that the sources of production (soil, water, and genetic resources) must be given attention equal to the traditional emphasis on production. The BIFADEC approach is to help build a national coalition for public awareness and for the purpose of evolving a common agenda for sustainable agriculture and natural resource management. Achieving sustainable production and resource protection will require a large and dedicated coalition of farmers, agribusinesses, environmentalists, academics, governmental agencies and the general public. In fact, sustainable agriculture will require everyone's efforts to make the necessary major shifts from the exploitative methods of the past. It is a job for all humankind.

This document was prepared by Dr. Gene Wilken, Professor of Geography in the Department of Earth Resources, Colorado State University. It is a basic statement of the promise and complexities of adopting sustainable agriculture as a global objective. Readers will find it useful in their efforts to make sustainable agriculture an effective tool for international development. It also may become an important part of the foundation on which the nation's common agenda for sustainable agriculture is built.

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Executive Summary

Sustainable agriculture is not a technique to be precisely defined, but a concept common to most environmentally-based economic activities. Simply put, it is that continued production depends upon maintenance of the resources on which production is based. It is a dynamic concept: Agroecosystems become more or less sustainable, and direction of change is more important than original state.

All ecosystems interact through the atmosphere, continental water systems, and oceans. In modern times the scale of environmental stress, a product of increased demand, creates effects that spread beyond local or national borders to impact on distant ecosystems. There are more participants in each transaction, and old patterns of environmental linkages and impacts and associated benefits and costs need reexamination.

The world's population has doubled since 1950 and is projected to double again in the next century. Consumption levels are also increasing. Together these represent a rapidly growing demand for food, fiber, and forest products. The concept of sustainability must include the factor of growth. Most increased demand will come from rapidly growing urban areas. Rural population growth will continue to put pressure on the land, and encourage migration to the cities.

Since there are not enough durable or easily managed lands to meet the vastly increased global demands of the next century, marginal lands vulnerable to degradation will be pressed into service. Although some new technologies show promise, agriculture will continue to depend on soil, water, and other resources. The solution lies less in availability of particular types of land, and more in a variety of management methods which can achieve acceptable levels of production on many types of land. A new classification is called for that would include managerial potentials for sustainable production.

Sustainability is rightly viewed holistically. But broadening the concept too much risks confusing ecologic processes with socially defined concepts of equity, and may generate opposition to sustainable programs. The primary focus of sustainability should remain agronomic.

Since sustainability is a concept familiar to most farmers, destructive, non-sustainable practices need explanation. Circumstances that lead to poor practices include ignorance of environmental processes, new or inappropriate technology, inadequate managerial resources, unfamiliar ecosystems, restrictive land tenure arrangements, population pressure, climate change, and government policies. External circumstances may so deform on-farm decision-making environments that rational farmers choose non-sustainable practices.

Despite the logic of sustainable agriculture, there are inherent conflicts in the concept itself. These arise from trade-offs between production and conservation, resource allocation, short- and long-term objectives, differing participant perspectives, and incongruities in time and space. The primary purpose of a sustainable agriculture policy is to resolve these conflicts.

Ecologic and economic accounting differ in their use of indicators, scale, and time. They also lack common linkages. Economic price and tax policies contribute to the problem. Beneficiaries of resource use are not necessarily those who bear maintenance costs. Increasing scale of resource use has vastly expanded the number of participants in each transaction, and the complexity of economic accounting systems.

Implementing sustainable agriculture will require integrating production and conservation, and developing new indicators and monitoring procedures, land classifications, and management methods for both prime and marginal lands. Conflict resolution and incentives must consider all participants, including individual producers, consumers, national governments, and donor agencies.

The concept of sustainable production is not time-bounded. Yet it is unrealistic to expect supportive policies and programs to endure. The solution is self-sustainability, in which practices that preserve the resource base and promote increased production are maintained by economic incentives.

Sustainable agriculture, governed as much by economics as by ecology, is the inevitable solution. Despite uncertainties, it offers the best framework within which conflicts can be identified and resolved.

INTRODUCTION

The concept of sustainable agriculture has swept through the development community with breathtaking speed and force. Despite unresolved problems of application and even of definition, sustainability has been adopted as policy by a broad spectrum of agencies and First and Third World governments. Academic and research communities have been equally enthusiastic, recognizing in sustainability a concept that encompasses the objectives of many specific approaches such as low-input agriculture, minimum tillage, and integrated pest management.

Sustainable agriculture defined

Sustainable agriculture is not a technique to be precisely defined, but a concept common to most environmentally-based economic activities. Simply put, it is that continued production from agroecosystems depends upon maintenance of the resources on which production is based. It is a dynamic concept, actually more concerned with process than condition: Agroecosystems become more or less sustainable and the important quality is direction of change. Growth is an essential factor in the concept of sustainability: Not only maintain but also increase levels of production while at the same time, not only conserve, but also enhance resources, so that the world's agroecosystems can provide more food, fiber, and forest products indefinitely.

The essence of sustainablility is that continued production from agroecosystems depends upon maintenance of the resources on which production is based.

Few agroecosystems are ecologically or economically self-contained; most rely to a greater or lesser degree on inputs and outputs that make them vulnerable to external influences. But self-sufficiency should not be confused with sustainability. External inputs are but one of many links between agroecosystems and the larger environmental and social systems in which they are imbedded.

Few agroecosystems are ecologically or economically self-contained; most rely on inputs that make them vulnerable to external influences.

Global eco-interdependency

The idea of hierarchical and interlinked systems has been accepted in ecology for decades. Eventually all ecosystems interact through the great energy and mass transfer agencies of the atmosphere, continental water systems, and oceans. In earlier times, environmental stress was often local and effects were less frequently transmitted through ecosystem linkages on a scale that attracted outside attention.

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We have entered an age of global change and global ecological interdependence. Although this is due in part to more sensitive ways of measuring changes in physical and biological systems, increasingly it is the scale of stress, a product of increased demand, that creates effects that spread beyond local or national borders to impact on distant ecosystems. Waste discharges from European and American factories come down as acid rain on Scandinavian and Canadian forests. Widespread deforestation in Latin America and Africa threatens the global atmospheric CO_2 balance. Assaults on the environment have become matters of concern to countries and peoples far removed from the scenes of degradation. There are more participants in each transaction, and old patterns of environmental linkages and impacts and associated benefits and costs need reexamination.

THE PROBLEM IS DEMAND

The problems addressed by sustainable agriculture are not difficult to identify. They consist of rapidly growing demand for farm and forest products produced by using finite, degradable resources. Demand has two major components: population growth and increased incomes, thus necessitating growth as an additional dimension in the concept of sustainability.

Population growth

In 1950 the world's population was about 2-1/2 billion people. In less than 40 years it doubled to 5 billion. According to recent estimates, the population will double again, to 10 billion, before leveling off late in the next century. Other estimates place the ultimate population figure even higher.

Increased consumption

The demand to which the world's agroecosystems must respond is made up of two components. Population is not likely to stop growing soon and income may never stop.

In addition to increased numbers of people, consumption levels are also increasing. One goal of development (another universally accepted concept) is to increase incomes and improve standards of living. This will be expressed in part in increased consumption of food, fiber, and forest products. Thus, the demand to which the world's agroecosystems must respond is made up of two components, population and income. The first is not likely to stop growing until well into the next century. The second may never stop.

Where will the demand be expressed?

Rural and urban populations in the less-developed countries (LDCs) grow at quite different rates (Table 1, page 27). With the exception of Africa, rural populations are projected to increase at less than 1 percent per year. In some less-developed areas, most notably Latin America, agricultural populations will actually decline. In contrast, urban growth, driven by high rates of natural increase and immigration from rural areas, will exceed 3 percent. In addition to distinctive growth rates, rural and urban populations also express distinctive demands - one for productive resources and the other for products of agroecosystems.

Most population growth, and thus demand, will be in urban areas.

Rural demand

Despite relatively low growth rates, most rural sectors will have to absorb millions of additional people in the next few decades. Options for doing this are limited. Continued fragmentation of good lands is likely, although not desirable from either a production or equity point of view. Intensifying production is a practical alternative if yields can be increased with additional labor and management. In-country migration is feasible only if suitable lands are available. Continuing large-scale international migration offers only a partial solution. The bulk of the additional half-billion rural people projected for the LDCs will have three choices: Intensify production on existing lands, migrate to urban areas, or look for new lands, most of which will be marginal.

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Urban demand

Over the next 30 years urban populations will double and account for more than 85 percent of total world population growth. Most of the increased demand for agricultural products will come from expanding urban populations. The change from rural to urban consumption is not just locational, but also marks a change in dietary patterns. Urban diets commonly shift from basic subsistence to consumer preference, away from traditional cereals, roots and tubers, toward rice or wheat, and a wider range of vegetables and processed foods (including, regrettably, some foods which have high social, but low nutritive value). Urban buyers customarily make choices based on quality, appearance, and price. But they may also express preferences for particular production methods (e.g. less chemical use), thus creating

market forces that can guide agriculture toward sustainable practices. Urban demand for products grown under sustainable conditions can be a powerful incentive for changing agricultural practices.

Productive resources

The message is clear: The lands and technologies now in use are not adequate to meet present requirements, much less those of the future.

Increased demand for farm and forest products creates increased demand for productive agricultural resources which must be met by more intensive use of good farm lands or increased use of marginal lands, or both. Use of either can push agriculture into degradational modes in which short-term production gains come at the expense of long-term environmental stability. Since there are already many examples of deteriorating or collapsing agroecosystems, the message is clear: The lands and technologies now in use are not adequate to meet present requirements, much less those of the future.

THE PROBLEM IS SUPPLY

A prediction in 1950 that the world's population would double in less than 40 years would have been met with disbelief. Obviously such a rush of people would put intolerable pressure on the world's agroecosystems. That this unbelievable situation has come to pass and that the demands of a vastly increased population are being met, at least minimally, is one of the great achievements of the 20th century, testimony to the ingenuity and hard work of the world's farmers and agricultural scientists.

Feeding five billion, but at what cost?

This achievement has come at the cost of severely degraded agricultural resources. Signs of agroecosystem stress and even breakdown are abundant. Although often masked by environmental events, the cause, nevertheless, is population pressure. For example, drought is a normal element in Sahelian Africa; combining it with elevated human and animal populations and overuse of fragile steppe and savanna lands has proven disastrous. Similarly, powerful storms in the Bay of Bengal become catastrophes when they inundate the low lying, overpopulated deltas of Bangladesh. Less dramatic but more pervasive are the impacts of displaced farmers who have moved into forested or mountain regions. Traditional forest farming methods that were sustainable under light

population pressure break down under growing numbers and shorter fallow. Without appropriate management, deforestation and attendant losses of soil and water resources is inevitable.

Feeding ten billion - even higher costs?

What will be the result of again doubling the population? As demands increase, the areas where breakdowns occur will multiply, as will the magnitude of ecosystem disarray. A concerted, worldwide effort to anticipate the problems and devise management strategies is necessary to avoid further environmental chaos.

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Few new good agricultural lands

Few new prime or good agricultural lands remain undeveloped. Most of the durable ecosystems of the middle latitudes are already under cultivation, and most of the arid and semiarid areas where irrigation is feasible are being irrigated already. Previously improved lands, such as those that came under early irrigation projects and now suffer from poor drainage or salting, offer new frontiers for reclamation. In general, most of the world's good and even marginal agricultural lands already are in use.

Destructive use of poor lands

Under pressure from increased demands, formerly unused hilly, arid, and forested lands are being brought under cultivation, or are being cultivated more intensively. These marginal or fragile lands are vulnerable to rapid degradation. The process is self-defeating: Demand encourages use, and use degrades and lowers yields, thereby forcing producers to move on to even more marginal, vulnerable lands.

On fragile lands the process is self-defeating: demand encourages use, and use degrades and lowers yields.

How about new technologies?

Although technology continually changes the way resources are evaluated and used, relationships between agriculture and the natural environment are close and will remain so. Some new approaches, such as tissue culture and genetic engineering, show great promise, but are not likely to produce the dramatic yield increases needed to offset increased demand. Agriculture will continue to depend on the availability and quality of soil, water, and other resources.

Prime or marginal lands?

Prime or durable lands have low gradients and are not easily eroded, are well drained, inherently fertile and responsive to inputs, offer a wide range of crop or enterprise alternatives, and harbor a great reservoir of experience with use. With proper management they are capable of sustained cultivation. They are, however, susceptible to the negative effects of over-management, such as soil toxicity from chemicals, and salting and water logging from irrigation.

Marginal or fragile lands often occupy steep slopes, are poorly drained, of low inherent fertility and unresponsive to inputs, offer few crop or enterprise alternatives, and are relatively unknown with respect to inherent qualities and managerial techniques. They are more likely to suffer from under-management in which resources are depleted with use. Their biggest attribute is that they are available and offer at least minimal farming opportunities to growing populations of farmers. Most farmlands lie somewhere along a continuum between these extreme positions.

Realities of land scarcity

Thus the answer to the question, "Prime or marginal lands?" is "Both." Additional production must come from more intensive use of good agricultural lands and more extensive use of fragile lands.

Since there are simply not enough durable or easily managed lands to meet the vastly increased global demands of the next century, many types of land will be pressed into service. On the local level, many countries have no choice. With little good agricultural land and rapidly growing populations, they must bring marginal, even extremely fragile, lands into production. Thus the answer to the question, "Prime or marginal lands?" is "Both." Additional production must come from more intensive use of good agricultural lands and more extensive use of fragile lands.

Need for new classifications

Conventional indicators of land quality, such as fertility, slope, and drainage, are inherent characteristics. But these are also factors that can be modified: Sloping fields can be terraced, poor soils amended, and drainage improved. On the other hand, good lands can be degraded if improperly managed. The focus of sustainability is on management to produce and also to conserve. The objective restated is to use durable lands more intensively, yet not over stress them, and use marginal lands more extensively, yet avoid degrading

them. The solution lies less in availability of particular types of land, and more in management methods which can achieve acceptable levels of sustainable production on a variety of lands.

A new classification is called for that includes not simply inherent characteristics but also managerial potentials for sustainable production. Under these criteria, good lands would not necessarily be those with superior inherent production qualities, but those that could be managed so that production is maintained or even increased, while at the same time resources are conserved or even enhanced. The critical element would be management costs in relation to the combined benefits of production and resource maintenance.

SUSTAINABILITY, AGRICULTURE, AND SOCIETY

It is popular to view sustainability holistically. To be sustainable, agriculture not only must be ecologically sound, but also economically profitable, socially equitable, and politically supported. Theoretically the position has merit. Certainly farmers must see sustainable practices as beneficial, or they will not adopt or continue them. Since markets, consumers, and governments have much to do with the rewards that go to farmers, the whole society ultimately is directly or indirectly involved. Truly sustainable systems are affected by all the economic and social factors, including equity and justice.

To be sustainable, agriculture must be ecologically sound, economically profitable, socially equitable, and politically supported.

Different bases for defining ecologic and social sustainability

There are risks, however, to expanding the scope of sustainability too far. The first concerns definitions. On the one hand, plant and animal requirements define the conditions that ultimately determine what is or isn't agronomically sustainable. These conditions remain relatively constant with respect to time and place. On the other hand, the conditions that determine economic and social sustainability are based on knowledge and values that vary between cultures and over time. What is considered socially or economically equitable, or just, or sustainable in one society might be interpreted quite differently in another place or time. Most farmers and agricultural scientists could probably

agree on the factors that contribute to agronomic sustainability. Developing universally acceptable definitions of social and economic sustainability would be more difficult.

Social change as obstacle

If sustainability is adopted as the guiding concept of agricultural development, it must be translated into specific objectives and practical interventions.

The second risk is pragmatic. If sustainability is adopted as the guiding concept of agricultural development, it must be translated into specific objectives and practical interventions. The goal is to make progress toward sustainable agriculture under a wide variety of environmental and social conditions. However, if sustainability is made contingent on major social changes, it surely will encounter strong resistance from many quarters, making it unlikely that the concept will spread rapidly into many parts of the world.

Rationale for the agronomic basis for sustainability

Despite the interrelatedness of ecologic and socioeconomic systems suggested above, the primary focus of sustainability remains agronomic. Other factors assume importance insofar as they aid or inhibit the productive use and conservation of agricultural resources. Economic systems contribute to sustainability if they allow farmers to redirect sufficient resources to preserving and enhancing agricultural environments. Positive government policies are those that promote rational resource use and conservation. Perhaps the best approach would be to focus on those economic and social factors that bear directly on sustainability in agriculture by encouraging or discouraging rational production and resource conservation.

Sustainable agriculture, sustainable societies

Robust resource bases and productive agricultural systems provide societies with the strength and flexibility to go beyond subsistence concerns.

Social and economic systems perform a supportive role with respect to sustainable agriculture. The relationship goes both ways: Robust resource bases and productive agricultural systems provide societies with the strength and flexibility to go beyond subsistence concerns and redefine what is socially and economically just, equitable, or desirable. Preserving resources preserves alternatives so that future generations will have more choices regarding standards of living, social forms, and directions of development. Supportive social and economic factors contribute to the sustainability of agroecosystems, and healthy agricultural sectors support sustainable societies.

ENVIRONMENTS OF ERROR

Sustainability is not a new concept in agriculture. Most farmers understand well enough the flows of energy, moisture, and nutrients that affect the quality of their fields and pastures. Most farmers likewise understand the relationship between resource maintenance and production, and their own role as resource managers. This season's lower yields sternly remind them of last year's neglect of soil fertility. Today's investment in conservation will be returned tomorrow in lower system maintenance costs. In agriculture, sustainability is common sense, and good resource management practices are found all over the world.

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The mystery of nonsustainable agriculture

Bad, nonsustainable practices also are found all over the world and with predictable results: Soil erosion, salting, chemical pollution, and water losses are widespread and increasing. If agricultural resources are so important and so threatened, why aren't they being properly managed? If farmers know better, why aren't they making better decisions about resource management? In short, why do farmers do such irrational, self-destructive things?

Environments of decision-making

To understand decisions, good or bad, it is necessary first to understand the environments in which decisions are made. If serious mistakes are being made consistently, perhaps there are environments that encourage error. Since agriculture is a nexus of agronomic, economic, and social considerations, the analysis will lead us far from strictly on-farm decisions and into areas where ecologic and social considerations are in conflict. It is exactly in those areas where many of the errors are found.

The case of the ignorant farmer

One of the most popular figures in development circles is the well-intentioned, but ignorant farmer who continues his traditional, low-yield, destructive practices simply because he knows no better. The solution is obvious to local and foreign technical experts: Design extension programs to teach farmers proper procedures.

Certainly lack of farmer sophistication can be a factor. All farming sectors have poor managers who, because of ignorance, sloth, disability, or disinterest, continue obviously destructive practices. However, most farmers have mastered the rudiments of agronomy, agricultural engineering, and farm management or they wouldn't survive. It is probably safer to assume that consistent error is due to factors other than farmer ignorance.

The case of inappropriate technology

Horror stories of misplaced technology fill the development literature. Examples include over-fertilized fields in Africa, tractor-induced erosion in Latin America, and salt ruined soils in Asia. Many incidents can be traced to donor zeal: Foreign advisors often make recommendations from their own experience without regard for different, unfamiliar environmental and social conditions. (See above: Extension programs for "ignorant" farmers.)

Before casting technology in the villain's role, we should distinguish between inherently bad technology and good technology badly applied. For example, criticisms of agricultural chemicals often arise not from inherent characteristics, but rather from improper use, as when excessively applied fertilizers or biocides contaminate adjacent lands and waterways. Other examples are tractors of inappropriate size, and water logging by poorly designed irrigation systems. Even though not inherently destructive, technology can be nonsustainable if misapplied.

Sustainable agriculture does not exclude the use of fossil fuels and chemicals; it only requires that appropriateness and sustainability be applied.

The concept of sustainable agriculture does not exclude the use of fossil fuels and chemicals; it only requires that the criteria of appropriateness and sustainability be applied to the whole system. If a farm subsystem is thriving, but its operations jeopardize the environment or consumers, the system as a whole is not sustainable.

The case of new technology

Analogous situations arise when farmers are confronted with unfamiliar new crops or technologies. This is particularly true when introductions represent major changes from previous experience. Irrigation in formerly rainfed systems or mechanization in formerly manually- or animal-powered systems are examples where lack of experience can result in

inappropriate practices and resource degradation, particularly during initial adoption and learning periods. Especially pernicious are new technologies with environmental effects that are not manifested directly. For example, agricultural chemicals impact on wildlife only after they have worked their way through food chains in ways that escape even the most observant farmer.

Agricultural technology consists of tools and knowledge, the hardware and software that make up a coherent package. If a component is missing, the technology will likely fail. The fault lies not in the farmer or the tools, but in the fact that the whole system was not transferred. Trial and error are the ways that farmers everywhere learn about new crops and tools and adapt them to their particular conditions. Negative aspects of new technology are difficult to anticipate and can lead to nonsustainable practices.

The case of inadequate managerial resources

Another popular figure in development is the farmer who lacks financial means to acquire the inputs or labor necessary to manage his or her lands. Governments and donor agencies typically respond with credit programs. These may introduce management problems with the credit itself, or with unfamiliar technology, since these programs often encourage acquisition of new tools and disregard existing methods of land and water management. The sustainable approach minimizes credit risk by incorporating local, environmentally benign technology and reducing dependence on purchased inputs. The challenge is to devise mixes of new and traditional methods that will increase production, yet conserve resources.

The case of the new environment

Experience, the great teacher in agriculture, is as site-specific as the climates and soils that characterize particular regions. Immigrant colonists can easily misinterpret environmental conditions in new places, often with disastrous results. As population and economic pressures force more and more farmers into unfamiliar, fragile environments, opportunities for environmental misinterpretations will multiply.

There is need for a comprehensive program of research on management, especially on the sorts of marginal lands that migrants will settle. Not all the solutions will come from laboratories and experiment stations. Traditional farmers have coped with problematic lands for centuries, often with considerable success (i.e., sustainably). The experiments already performed and the lessons learned should not be ignored.

The case of land distribution and tenure

Poor land distribution is a major obstacle to rational use. In many countries, control of land resources has been uncoupled from quality of management or even economic considerations. Large tracts of good land are not optimally used, but are held for social or speculative purposes. The tragedy of maldistribution pertains not only to equity but also to environment. Absentee or economically unconcerned owners are less sensitive to environmental warning signals and resource depletion. Rigid tenure systems prevent the best managers from acquiring land and applying good practices, and from investing in land over which they lack security of tenure.

Land tenure and distribution are some of the most deeply rooted, vigorously defended arrangements in any society. Arguments for and against land reform are customarily couched in terms of social justice, equity, or production. However, growing demand and deteriorating environments are now of such magnitude that the economic welfare of whole nations is jeopardized. Freeing underused lands from inefficient management would go far toward resolving individual country and world food supply problems.

The case of population growth

The processes of change in agricultural communities are poorly understood. Some traditional farming systems adapt quickly to new conditions. In fact, there are some who argue that population pressure spurs agricultural change toward higher production through more intensive resource management. More commonly, however, system resilience and sustainability are overwhelmed by modern rates of population growth. Perhaps the most popular example is shifting cultivation, considered ecologically sound under light population pressure, but disastrous when populations explode.

Rural populations in the LDCs will continue to grow into the next century, and no system can be considered sustainable if it cannot accommodate anticipated increased numbers and increased demand. A framework of analysis is needed within which individual and community response to population pressure can be analyzed and sustainable systems devised.

No system can be considered sustainable if it cannot accommodate increased numbers and increased demand.

The case of climate change

Climate is the basic element of agricultural environments. If climate changes, agriculture also must change. Despite this critical relationship, there are few data and only fragmentary research on the impacts of climate change on agroecosystems. Traditional farmers, especially those in climatically variable environments, have accumulated vast experience with short- and long-term climate fluctuations, and have developed coping skills and mechanisms. These need to be investigated and analyzed in the context of projected climate changes to determine potential impacts on sustainability.

The case of government policies

Government interventions are either direct, as in development projects, extension programs, and subsidies, or indirect, through markets and taxes. In either situation, production and demand are partially uncoupled, and social preferences are distorted. Government policies that emphasize production without compensatory incentives for conservation may actually subvert farmers' sustainable efforts.

Government policies that emphasize production without compensatory incentives for conservation may actually subvert sustainability.

Utility of the concept of environments of error

The concept of environments of error shifts the focus away from farm decision-making and addresses the riddle of seemingly irrational practices in a larger context. It helps explain why farmers might knowingly contribute to the destruction of resources on which their livelihood depends. It also identifies conditions that contribute to error and could be corrected.

CONFLICTS IN SUSTAINABLE AGRICULTURE

The primary purpose of a sustainable agriculture policy is to resolve conflict.

The concept of sustainable agriculture seems intuitively sound. But there remains a nagging question: If sustainability is so self-evident and so sensible, why is a policy necessary? Close examination reveals that, despite the logic of sustainable agriculture, there are inherent conflicts in the concept itself. Furthermore, because of the multiple relationships between agriculture and other segments of society, additional conflicts occur within a context of increasingly complex systems. The primary purpose of a sustainable agriculture policy is to resolve these conflicts.

Production versus conservation

Although the objectives of production and conservation are commendable, they are not necessarily compatible. Agriculture is disruptive, changing vegetation patterns, disturbing soils, and modifying water and chemical balances. Some practices are more disruptive than others, but all have the potential for resource depletion and environmental degradation. To counter the negative effects, it is necessary to spend time, energy, and resources on system maintenance. These costs are incurred directly for conservation or fertility replenishment or indirectly by reducing levels of disruption (e.g., minimize tillage), either of which may reduce production (benefits).

Resource allocation

Even though most farmers understand the need for resource conservation to maintain production, two problems give rise to conflict. One has to do with allocation of scarce resources (e.g., time, energy) between production and conservation. For example, how much investment in terraces or drainage canals is justified by future production? How much additional effort to apply animal manure, as contrasted to convenient chemical fertilizer, is justified by beneficial effects on soil? Tradeoff decisions are all the more difficult since, although costs of conservation are apparent, benefits are often only intuitively determined. Even though cost-efficient, sustainable techniques exist or will be developed, trade-offs will continue to create conflicts in farmer decision- making.

Short-term versus long-term objectives

The second problem concerns the need to balance immediate results against future possibilities. If system maintenance costs jeopardize this year's profitability, survival may dictate maximizing production at the expense of conservation. The problem is common to agriculture everywhere and at every level where decisions are made. Small-scale farmers are strongly influenced by short-term needs, and rightly so; the consequences of reduced harvests can be severe. At the national level, demands of rapidly growing urban populations will make it difficult for governments to pursue sustainable programs that require substantial diversion of resources from immediate production.

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Conflicts of participant objectives

Agriculture is the basic activity, linking entire social systems in a web of production, distribution, and consumption. Little wonder that farmers attract attention (and gratuitous advice!) from many quarters. Perspectives vary, and the objectives of farmers may not be those of government, nor government's, those of consumers. For example, a government goal may be to increase production to meet export demand and generate foreign exchange. But farmers are understandably wary, having learned that increased production can lower prices and reduce incomes. Continued lower prices may force farmers to ever higher levels of production simply to maintain income levels, with predictable impacts on resource conservation. Meanwhile, the emphasis on export crops diverts resources from domestic food production to the detriment of consumers.

Conflicts in time

Agriculture operates simultaneously in the worlds of ecology and economics, each of which marks time by different clocks. Production is bound to ecologic cycles that vary from seasonal and annual vegetables and grains to long-term perennial shrubs and trees whose life may span decades. Similarly livestock ranges from short-lived poultry to longer-term dairy and beef animals. Tools and experience represent long-term investments as do system maintenance and enhancement.

Agricultural products, on the other hand, are harvested and sold each season or year, and prices can vary dramatically from one harvest to the next. Farmers must commit to specific products months or years before they have indications of prices or profits. Adding short- and long-term climate variables that impact on yields complicates the situation. Agriculture deserves its reputation as a risky business.

New standards

Consumer concern over production methods and product quality may lead to whole new sets of market variables, the dimensions of which are only dimly perceived at this time. For example, demands for chemically free fruits and vegetables may lead to lower standards for pest damage and blemishes. Will these become universal, or will they simply create many new standards of chemical use and product quality? Since the new criteria apply to production methods, not simply product characteristics, the market alone cannot judge, and mechanisms must be created to establish standards and rules, with penalties for noncompliance. For farmers this is another area of potential risk.

Coping with risk

Sustainability, which ostensibly adds stability to a system, may actually reduce flexibility and exacerbate short-term risk.

Farmers have limited options for coping with these uncertain situations. Spreading risk through multiple products or shifting crops from year to year is difficult, especially as sophisticated market demands and production systems require increasingly specialized equipment and knowledge. Ironically, sustainability, which ostensibly adds stability to a system, may actually reduce flexibility and exacerbate short-term risk by emphasizing long-term investments and concomitant allocation of resources and higher levels of management.

Conflicts in space

Ecosystems are integrated in space by transfers of energy and water. The river basin concept illustrates this principle at the local or regional level: Disparate physical environments (e.g., hill lands, river valleys) and social groups (e.g., herdsmen, farmers, urban dwellers) are joined in a common, interdependent region in which activities in one area or by one group (e.g., deforestation, erosion) are transmitted to others (e.g., increased runoff, siltation) by the integrating

river system. Clearly, none of the component subsystems can be considered sustainable if they reduce sustainability in the others.

ECOLOGIC AND ECONOMIC LINKAGES

Earlier the notions of demand growth and linked ecosystems was introduced to explain why local environmental disruption is now of global concern. Linkages, feedback, and response to disruption are basic to the concept of ecosystems.

Ecologic and economic accounting

Environmental indicators, such as erosion, water quality, and plant response act as stern auditors of ecosystem energy, mass, and nutrient accounting. By contrast, economic accounting of ecosystem use is imperfectly developed, and some elements that are crucial to sustainability are missed. For example, although costs of most conservation measures are known, benefits are only crudely estimated. At the farm level, returns on conservation and resource enhancement practices are mostly taken on faith, a shaky basis for calculating tradeoffs with production. Assessing the profitability of various agricultural systems will require individual farm and national accounting that accurately reflects conservation benefits and costs, and resource deposits and withdrawals that occur with ecosystem use.

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Economic and ecologic accounting systems are incongruent also with respect to scale. Although divisions of the environment - for example, micro- meso- and macro-scale climate or soil systems - are made for convenience, no one questions that the biosphere is a vast continuum linked by transfers of energy and water, and that exchanges take place freely between arbitrary divisions. Economic divisions of scale are also somewhat arbitrary, but accounting systems make them real. The farm, municipality, state or province, and nation are all covered by separate balance sheets and income statements, and it is often difficult to trace transactions between them. Since things of value are involved, the transactions themselves are also subject to dispute and negotiation. The result is that the economic feedback and response system does not parallel the ecologic. Without matching economic linkages, the feedback loops of rewards and penalties that should reinforce sustainable practices are broken.

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Policies as problems

Domestic price policies, taxes, and subsidies impact differently on the combined objectives of production and conservation than they do on either one alone. For example, low tariffs or subsidies may favor use of chemicals over other forms of fertility or pest management. Domestic sustainability is also affected by foreign policies. Farm subsidies in developed countries may create surpluses which, when sold at concessional rates abroad, undermine farm prices and policies of recipient countries. Will governments be able to modify production policies to stimulate sustainable practices? Will developed countries be willing to consider the impacts of their domestic farm policies on sustainable agriculture in the LDCs?

Benefit receivers not necessarily cost bearers

Integrating economic and ecologic accounting is further complicated by the fact that those who benefit from resource use are not necessarily those who pay for resource maintenance.

Integrating economic and ecologic accounting is further complicated by the fact that those who benefit from resource use are not necessarily those who pay for resource maintenance. Some examples are spatial, as when farm chemicals contaminate downstream or subsurface water systems. Some are social - for example, privately exploited and degraded lands that are reclaimed at taxpayers' expense. Perhaps the most reprehensible are temporal, when costs of present environmental desecration fall on future generations. The relationships are not mutually exclusive. A government subsidized logging activity (transfer between social sectors) that accelerates erosion and jeopardizes downstream water systems (spatial transfer) and incurs costs of reclamation that are passed on to future generations (temporal transfers) incorporates all three.

The scale of environmental disruption complicates these issues. New farms hacked out of rainforests in Brazil, Zaire, or Indonesia may or may not be sustainable, depending on whether farmers allocate adequate resources to system maintenance. Even if they are sustainable as local systems, are they sustainable from a regional or national perspective? Making that determination would require national accounting of costs of system maintenance and resource depletion (forest loss) in comparison to benefits that might include not only production, but also employment.

The task is not finished. Benefits and costs of forest clearing escape local, regional, and even national boundaries. Agricultural colonists regard the trees in negative terms - something to be removed so they can get on with farming. National governments consider the timber as a source of needed foreign exchange. In contrast, the international community values intact forests for their capacity to cycle water and oxygen and shelter biological diversity. Who decides whether resource losses outweigh the production and employment gains of farming or logging? Demand growth and scale of activities have increased enormously, as have the number of participants and value systems.

THE CHALLENGES OF IMPLEMENTING SUSTAINABLE AGRICULTURE

Despite the formidable challenges suggested above (and others surely yet to come), sustainable agriculture is not only worth pursuing, it is inevitable. Deterioration of the world's agroecosystems and increasing future demand are joined problems that call for joined solutions. It seems likely that sustainability, by whatever name, will be the overriding focus of agricultural development efforts for the rest of this century and beyond, and that future agricultural policy and development projects will be formulated within a sustainability framework.

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New approaches

Farmers appreciate the close connection between production and resource preservation, and in many cases have developed sustainable systems. Development and government agencies have enthusiastically embraced the concept. Although some organizations and individuals may gain in the short term by avoiding environmental maintenance costs, in the long run all parties benefit from rational resource use. The challenge is not to convince, but to resolve conflicts and remove obstacles to sustainable agriculture. For this, new approaches are needed.

Integrating agronomic aspects of production and conservation

The foundation of sustainable agriculture is a healthy resource base and a balanced relationship between production and system maintenance. This is also a well-researched area, and a great deal is known about plant, soil, and water relationships and management techniques. Since the emphasis traditionally has been on production, resources are classified, and agricultural systems are evaluated in production terms. Introducing sustainability as a parallel goal will require reappraisal of agricultural resources and systems efficiency.

Measuring and monitoring agronomic sustainability

There are a number of ways to measure and compare agricultural production - for example, by units of area or labor, and monetary or energy value. Measures of environmental resources are less exact, and many deal only with degradation (e.g., soil loss) rather than maintenance or enhancement. Combining production and conservation will require new measures that reflect values, tradeoffs and increments of change. For example, reducing soil erosion may incur additional management costs; lowering chemical inputs may result in higher pest damage. How much gain in one aspect compensates for reduction in the other? Until relationships and verifiable indicators are developed, it will be difficult to monitor progress toward sustainability.

Classifying sustainable lands

Land classification has traditionally been oriented toward either production or conservation. Sustainable agriculture includes both objectives and needs a classification system that also includes management potential for sustained production under a wide variety of environmental conditions.

Intensive use of land already cultivated

Future demands will be met mostly by increased output from lands already under cultivation. This will call for research on even more intensive fertilizer and water management and crop development. Less disruptive practices offered by such subfields as agroecology, low-input agriculture, and integrated pest management will assume new importance.

Use of marginal and fragile lands

There will be increasing pressure on heretofore unused weak soils, hill slopes, and humid tropical forests - marginal and fragile lands that have been largely ignored by the scientific community. There is a desperate need for greatly increased research, including analysis of traditional methods, and development of new, sustainable agronomic practices for these relatively unknown, easily damaged lands.

Site-specific management for sustainability

Each agroecosystem is unique, and what is sustainable in one place may not be in another.

As the name implies, agroecosystems are combinations of environmental elements, cultivation practices, and social and economic institutions. Such complex combinations of elements produce a high degree of site specificity. If each agroecosystem is unique, it follows that sustainable agricultural practices will also vary with location, and what is sustainable in one place may not be in another. For example, where labor is abundant, labor-intensive methods are efficient, whereas in labor-scarce situations they are impractical. Similarly, chemical amendments under some conditions are the antithesis of sustainability, whereas in others they might bring stability.

The corollary to this is that there are no universal prescriptions for sustainability. Some techniques, particularly those that minimize external inputs, are often promoted as inherently sustainable. But all approaches must be judged within the context of particular locations. Much needed are reappraisals of specific combinations of environmental and social conditions, and inventories of available management practices. Guides to the absorptive capacity of various types of land for various types of management would be especially useful.

Inventories of site-specific agroecosystems

Useful surveys of soils and agroecological properties have been made in many regions during the last few years. Other resources, such as climate, need to be recorded and mapped at scales appropriate to individual projects and small regions. In addition, inventories of successful (i.e., sustainable) and unsuccessful (i.e., nonsustainable) agricultural systems are needed. These should contain details not only of field methods, but also of essential social and economic elements.

Distributions and correlations of site-specific data could be mapped and analyzed using geographic information system (GIS) technology.

Determining user-beneficiaries and sharing costs

Sustainable production depends on systems that link resource users with environmental costs, so that ecologic feedbacks are reflected in economic accounting. The scale of environmental disruption has complicated matters, since beneficiaries and cost-bearers may be located far from places of actual resource use. Institutional arrangements for determining and allocating costs are needed, so that individuals, governments, and the international community can make rational decisions.

Resolving conflicts of time: Long-term conservation, short-term production

Production and conservation are sometimes conflicting objectives. Time is a major factor. Most agriculture is on seasonal or annual cycles; conservation efforts take decades; true sustainability is reckoned over indefinite time. Conflicts between participant groups impacted differently by the long-term aspects of sustainability programs are inevitable. Agroforestry projects, which also are inherently long-term, have frequently encountered this type of conflict, and we should not expect agricultural projects to be exempt. Reconciling investments in long-term sustainable agriculture with farmers' short-term needs will require creative plans and policies at every step.

Resolving conflicts of space: Spatially integrated economic systems

Ecologic systems, such as stream basins, are integrated spatially by the mobile elements of the environment (energy, water, wind) that transfer effects (e.g., eroded soil) from one place to another. Economic systems must be similarly spatially integrated, in order to account for positive and negative transfers. For example, hillside farmers will be encouraged to invest time and effort in conservation if they share in the benefits of downstream irrigation systems which non-sustainable practices might threaten. Devising benefit and cost streams that parallel ecologic flows is one of the major challenges of sustainability.

Cautious introduction of new technologies

New technologies always stimulate hope. But past experience has shown that even ostensibly benign innovations can have negative impacts. Maintaining the dual standards of production and resource maintenance requires even closer scrutiny of new methods to ensure that they are compatible with the physical, social, and economic environments of particular places. Agrotechnology transfers should be subjected to the sort of negative analysis imposed on engineering structures when failure carries high costs.

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Experience transferable both ways

In the past, technology transfers were almost always from technically-advanced to less-advanced countries. Sustainability puts more emphasis on system maintenance and management and less on technical solutions. Contributions can come from any source at any technical level. Although specific methods will differ from place to place, there will be many opportunities for two-way exchanges. This will require new procedures for information and technology transfers.

Transferring traditional technology

Traditional practices have evolved over generations under particular sets of environmental and social conditions. Characteristically they are resource-conserving and rely on local inputs. They offer a pool of rich and varied alternatives to modern technology and are increasingly finding acceptance in the development community. Inventories and analyses of traditional practices, including the physical and social circumstances in which they operate, would reveal the potentials of this long overlooked resource and possibilities for wider application. Traditional technology, like any other, should pass tests of ecological, economic, and social compatibility and sustainability before being transferred.

Motivation and incentives for farmers and governments

Will farmers be able to forego short-term gains? Will government agencies be willing to invest scarce resources in long-term practices?

Implementing sustainable agricultural practices will quickly encounter questions of motivation and incentives. Will farmers be able to forego short-term gains of production for long-term benefits of conservation? For that matter, will government agencies be willing or able to invest scarce resources in long-term sustainable practices when present needs are so imperative? If special incentives are required for farmers and governments, who will provide them? The effects of vastly increased environmental degradation transmitted through interlinked ecologic systems over wider and wider areas impact more and more people. There are so many participants in each transaction that determining benefits and allocating costs for system use and maintenance will pose a major challenge.

Motivation and incentives for development agencies

Since sustainability lacks the high visibility and short-term payoffs of other projects, development agencies themselves will confront the problem of making the necessarily long-term commitments to sustainable agriculture in the face of competition from other, more visible programs. Even if development agencies find it feasible, can they convey the wisdom of long-term sustainable programs to those who formulate their budgets?

THE ULTIMATE SOLUTION: SELF-SUSTAINABILITY

Sustainable agriculture is forever, but policies are not.

Like the concept of development itself, sustainability is not bounded by time. For example, it would be contradictory to speak of agricultural systems that were sustainable for only fifteen or fifty years. Nevertheless, these periods are well beyond the planning horizon of most economic and social organizations. No matter how powerful or imperative the concept seems now, it is unrealistic to assume that present enthusiasm for sustainability will never wane, or other issues never take its place in the hearts and minds of government planners and donor agencies. Can sustainable agriculture last without policies and programs to support it? Sustainable agriculture is forever, but policies are not, so how shall it endure?

Sustainable agriculture is a mixture of ecologic, economic, and social factors. The factors controlled by natural processes are relatively constant and need no reaffirmation by policies. Economic and social choices are based on perceptions and values that vary among places, times, and participants. Differences of time, space, scale, and perceptions create environments of error and of conflict. Solutions to technical problems of sustainability, such as reducing environmentally harmful inputs or managing fragile lands, are available or can be developed. However, as long as nonsustainable practices are rewarded economically or politically, nonsustainable agriculture is inevitable.

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Thus, achieving sustainability depends on social and economic factors. What social processes can match the permanency of environmental processes? Although imperfect, economic institutions, such as markets, seem to offer the best solution. Future population growth and development may even strengthen economic forces, even as past growth has produced current concerns. Increasing demands will place higher values on resources. Appreciation of the connections between environmental health and human health will swing consumer preferences toward products of sustainable systems.

The need for intervention is clear. Demand growth has overwhelmed the capacity of agroecosystems to adjust, and research organizations to innovate. Policies to bring production and conservation into balance are needed before resource losses reduce future options. Policies should also be aimed at strengthening economic systems. Access to productive resources should be coupled to managerial competence. Land use should reflect societal needs. Farm and national accounting should parallel ecosystem budgets, so that environmental signals are transmitted clearly through economic systems. Costs should be linked to benefits, so that even distant participants share in system maintenance. Programs launched now in the enthusiasm of a powerful concept should recognize the transient nature of policy and include measures for phasing out support and creating self-sustainable systems.

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CONCLUSION

Providing for twice as many people at higher rates of consumption, yet avoiding disastrous impacts on the environment are bold objectives. It is not clear how they will be achieved.

The objectives of sustainable agriculture are more a description of needs than a plan of action: Increase production, yet conserve resources; provide for twice as many people at higher rates of consumption, yet avoid disastrous impacts on the environment. These are bold objectives, and it is not at all certain how they will be achieved. The present and past offer little reassurance. Demand growth and environmental degradation are closely correlated, even in prosperous countries.

Yet if we are to convey to those who follow not only the resources on which to base adequate lives, but also choices and hope, we must realize these objectives. We must develop systems of production that satisfy growing needs and also maintain and enhance the agricultural environment on which production depends. New production and conservation practices are needed, as are accounting systems and policies that reconcile differences. The challenges are formidable and the route uncertain. But would any other course be acceptable?

The concept of sustainability recognizes that agriculture is governed as much by economics as by ecology, by laws of supply and demand as by principles of system maintenance, and that conflicts will inevitably arise. It offers a conceptual framework within which these conflicts can be articulated and the best approach for resolving them.

Table 1. Urban and rural populations, 1990 and 2020

	----1990 Population----			----2020 Population----			----Percent Change----		
	Total	Urban	Rural	Total	Urban	Rural	Total	Urban	Rural
		millions			millions		-pct-	-pct-	-pct-
World	5292	2260	3031	8062	4649	3413	52	106	13
More Developed	1205	875	329	1340	1050	290	11	20	-12
Less Developed	4086	1384	2702	6722	3599	3123	65	160	16
...Africa	647	223	424	1441	787	653	123	253	54
...Asia[1]	2985	835	2149	4550	2206	2344	52	164	9
...Latin America	448	324	123	719	600	118	60	85	-4
...Oceania[2]	6	2	4	11	5	6	83	150	50

[1]Does not include Japan

[2]Does not include Australia or New Zealand

Source: UN, Prospects of world urbanization, 1988.

SELECTED REFERENCES

Blake, R. O., 1988
The transition to sustainable agriculture: An agenda for AID.
Washington, D.C.: International Institute for Environment and Development, Committee on Agricultural Sustainability for Developing Countries.

Board for International Food and Agricultural Development, 1988.
Environment and natural resources: Strategies for sustainable agriculture.
Washington, D.C.: USAID/BIFAD, Occasional Paper No. 12.

Board on Science and Technology for International Development, 1989.
Overcoming hunger.
Washington, D.C.: National Research Council, BOSTID Developments, Volume 9.

Bromley, D. W., 1985.
Common property issues in international development.
BOSTID Developments 5(1):12-15.

Davis, T. J., and I. A. Schirmer (eds.), 1987.
Sustainability issues in agricultural development.
Washington, D.C.: The World Bank.

Douglass, G. K. (ed.), 1984.
Agricultural sustainability in a changing world order.
Boulder: Westview Press.

Edwards, C. A., R. Lal, P. Madden, R. H. Miller, and G. House, 1990.
Sustainable agricultural systems.
Ankeny, Iowa: Soil and Water Conservation Society.

Food and Agriculture Organization of the United Nations, 1989.
Sustainable development and natural resources management.
Rome: FAO/UN, Conference Document C 89/2-Sup. 2.

General Accounting Office, 1990.
Alternative agriculture: Federal incentives and farmers' options.
(Report to Congressional Requesters)
Washington, D.C.: U.S. GAO, GAO/PEMD-90-12.

Groenfeldt, D., 1989.
Farming systems and environmental quality: Impacts and interactions.
Washington, D.C.: Osborn Center for Conservation and Development,
World Wildlife Fund/The Conservation Foundation.
Fayetteville: 9th Annual Farming Systems Research/Extension Symposium.

Hendry, P., 1988.
Food and population: Beyond five billion.
Washington, D.C.: Population Reference Bureau, Population Bulletin 43.

Hildebrand, P. E., 1989.
Agronomy's role in sustainable agriculture: Integrated farming systems.
Las Vegas: American Society of Agronomy, Annual Meeting.

Hutchinson, F. E., 1989.
Opportunities and implications for U.S. universities in international
sustainable agriculture programs.
Washington, D.C.: National Association of State Universities and Land-Grant Colleges.

Mellor, J. W., 1988.
Sustainable agriculture in developing countries.
Environment 30(9):7.

Myers, N., 1989.
Making the world work for people.
('Sustainable development' is the new buzzword for saving the Earth,
but what exactly does it mean?)
International Wildlife Nov.-Dec.:12-14.

National Research Council, 1989.
Alternative agriculture.
Washington, D.C.: National Academy Press.

Panayotou, T., 1989.
The economics of environmental degradation: Problems, causes, and responses.
Cambridge: Harvard Institute for International Development/USAID.

Penn, R. J., 1972.
Environmental aspects of natural resource management.
Rome: FAO/UN.

Pezzey, J., 1989.
Sustainability, intergenerational equity, and environmental policy.
Boulder: University of Colorado, Institute of Behavioral Science.

Pimentel, D., T. W., Culliney, I. W. Buttler, D. J. Reinemann, and K. B. Beckman, 1989.
Ecological resource management for a productive, sustainable agriculture.
Food and Natural Resources, pp. 301-323.
New York: Academic Press, Inc.

Postel, S., 1990.
Toward a new "eco"-nomics.
World Watch Sep.-Oct.:20-28.

Ragland, J., 1989.
Agricultural, environmental, and resource sustainability.
Newport, Oregon: AUSUDIAP 25th Annual Conference.

Ragland, J., 1989.
Making sustainable agriculture an effective tool for international development.
Fayetteville: 9th. Annual Farming Systems Research/Extension Symposium.

Redclift, M., 1987.
Sustainable development: Exploring the contradictions.
London: Methuen.

Reganold, J. P., R. I. Papendick, and J. F. Parr, 1990.
Sustainable agriculture.
Scientific American 262(6):112-120.

Repetto, R., 1987.
Managing natural resources for sustainability.
Davis, T. J., and I. A. Schirmer (eds.),
Sustainable issues in agricultural development, pp. 167-181.
Washington, D.C.: World Bank.

Ruttan, V. W., 1988.
Sustainability is not enough.
American Journal of Alternative Agriculture 2&3:128-130.

Strong, M. F., 1989.
Ending hunger through sustainable development.
Tokyo: The Global Hunger Project, 3rd Annual Arturo Tanco Memorial Lecture.

Thomas, G. W., 1989.
Sustainable agriculture: Timely thrust for international development.
Washington, D.C.: National Association of State Universities and Land Grant Colleges, Division of Agriculture.

USAID, 1988.
Environment and natural resources: A.I.D. policy paper.
Washington, D.C.: U.S. Agency for International Development, Bureau for Program and Policy Coordination.

USAID, 1988.
An approach for sustainable agricultural development in the Sahel.
Tucson: Annual Donor Advisory Club Meetings, Discussion Paper.

Wilken, G. C., 1989.
Transferring traditional technology.
J. Browder (ed.),
Fragile lands of Latin America: Strategies for sustainable development, pp. 44-57.
Boulder: Westview Press.

Wilken, G. C., 1989.
Implementing BIFAD strategy on sustainable agriculture: Perspectives of the universities.
Fort Collins: BIFAD/USAID Title XII Regional Seminar.

Wilken, G. C., 1987.
Good farmers: Traditional agricultural resource management in Mexico and Central America.
Berkeley: University of California Press.

World Bank, 1989.
Sub-Saharan Africa: From crisis to sustainable growth.
Washington, D.C.: International Bank for Reconstruction and Development.

World Commission on Environment and Development, 1987.
(Brundtland Report)
Our common future.
New York: Oxford University Press.