2 Sustainable Agriculture in Developing Countries: Constraints, Challenges, and Choices

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The finitude of the biophysical resource base is increasingly apparent, particularly in the last two decades. The burgeoning population coupled with rampant human-induced degradation of the resource base has forced a re-evaluation of the human population-carrying capacity of the earth. Concerns are highlighted in a report by the World Commission on Environment and Development (WCED, 1987). This report provided the political awareness and incentives for a new approach.

CONCEPTS AND DEFINITIONS

Sustainable agriculture means a number of things to different people. For some, it is more of the same, while at the other extreme, the focus is on ecological integrity at the expense of any other concern. In industrialized nations, it includes basic economic concerns including imposition of purely aesthetic values such as pleasant scenery and noise abatement. Dahlberg (1991) posed a question—will these industrial societies seek to maintain current lifestyles, privileges, and consumption patterns—ironically using the label,

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sustainability—or will they seek to restructure into genuinely sustainable, equitable patterns? The same concerns apply to a lesser extent in developing countries. In the developing countries, the farmer's immediate concerns are crop yield improvement, crop diversity, and income enhancement which are the farmer's individual values. On the other hand, even in these countries, the visionary segment of the population or the institutional values may focus on things such as efficient cropping systems, pest control methods, potable water supplies, support for agrobased industries and related infrastructure. Consequently, it must be emphasized at the outset that it is necessary to define the concept of sustainable agriculture in the context of the society, and seek to attain a balance among the different segments of the society including individuals, institutions, markets, and governments.

Probably, the most elementary but important element of the concept is that its origin is in the value system of social, political, economic, religious, and other institutions. In time, as the idea of sustainable agriculture expands and strengthens, there will be divergent trends and sharp conflicts with some values, needs, and goals of people as individuals.

In the last few years there have been several meetings and publications dealing with the broad perspectives of sustainable agriculture (Edwards et al., 1990; Singh et al., 1990). The basic thrust of sustainable agriculture is the improvement of the quality of life in the context of an environmentally sound approach so that the resource base is maintained or enhanced for future generations. Depending on the institutions or countries involved, there are frequently additional points of emphasis and these are portrayed in the definitions given below.

From the FAO:

> Sustainable agriculture should involve the successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the quality of the environment and conserving natural resources (FAO, 1989a).

From Agriculture Canada:

> Sustainable agriculture systems are those that are economically viable, and meet society's needs for safe and nutritions food, while conserving or enhancing Canada's natural resources and the quality of the environment for future generations (Baier, 1990).

From the Technical Advisory Committee:

> Sustainable agriculture should involve the successful management of resources to satisfy changing human needs while maintaining or enhancing the quality of the environment and conserving natural resources (TAC, 1988).

From the USAID:

> Sustainable agriculture is a management system for renewable natural resources that provides food, income, and livelihood for present and future generations and that maintaining or improving the economic productivity of these resources (USAID, 1990, unpublished data).

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From Lynam and Herdt:

> A sustainable system is one with a non-negative trend in measured output (Lynam & Herdt, 1988)

The sentiments in these definitions are included in the three basic components of sustainability of Douglas (1984):

1. Sustainability as long-term food sufficiency, which requires agricultural systems that are more ecologically based and that do not destroy their natural resources.
2. Sustainability as stewardship, that is, agricultural systems that are based on a conscious ethic regarding humanity's relationship to future generations and to other species.
3. Sustainability as community, that is, agricultural systems that are equitable.

From these definitions, important institutional values (Eswaran & Virmani, 1990) are discriminatory use of land resources, conservation and enhancement of environmental quality, economic viability, increased and stabilized productivity, enhancement of quality of life, intergenerational equity, and buffered against risks.

The perception of sustainable agriculture is partly a function of the scale of operation, determined by the sphere of influence of the individual or group. The scale ranges from a farmer's field, a farm, a watershed, or a catchment, an ecosystem, a country and, finally, the continent, or the earth as a whole. Though the factors that affect sustainability at each of these levels and the kinds of interventions needed to make each more sustainable is different at each of these levels, the global picture must be appreciated to implement local actions.

To be effective, sustainable agriculture must include a concept of stewardship. While institutional values provide the framework for governments to respond, there are individuals and groups whose dedication and actions are needed to make sustainable agriculture work. Legal decree and economic subsidies without a strong sense of stewardship will result in conflicts, if not failure, in implementing sustainable agriculture projects.

Consequently the major ethic of sustainability at any level is stewardship and there can be no effort and incentive to implement a sustainable form of agriculture if appropriate stewardship is lacking. Thus, as shown in Fig. 2–1, stewardship is the most important component. There are many forms of stewardship and it has to start from the government through appropriate policy decisions and programs. Just as governments have invested to seek self-sufficiency in food and fiber production, they also must invest public funds to attain sustainability. This is particularly crucial in developing countries and in the absence of this support, sustainable agriculture is not tenable. Once appropriate policy and programs are in place, stewardship then becomes a responsibility of other levels in society such as social organizations and down to the farm family.

The motivation towards this form of agriculture listed in Fig. 2–1 applies to all levels of society though at any particular level, one may be more

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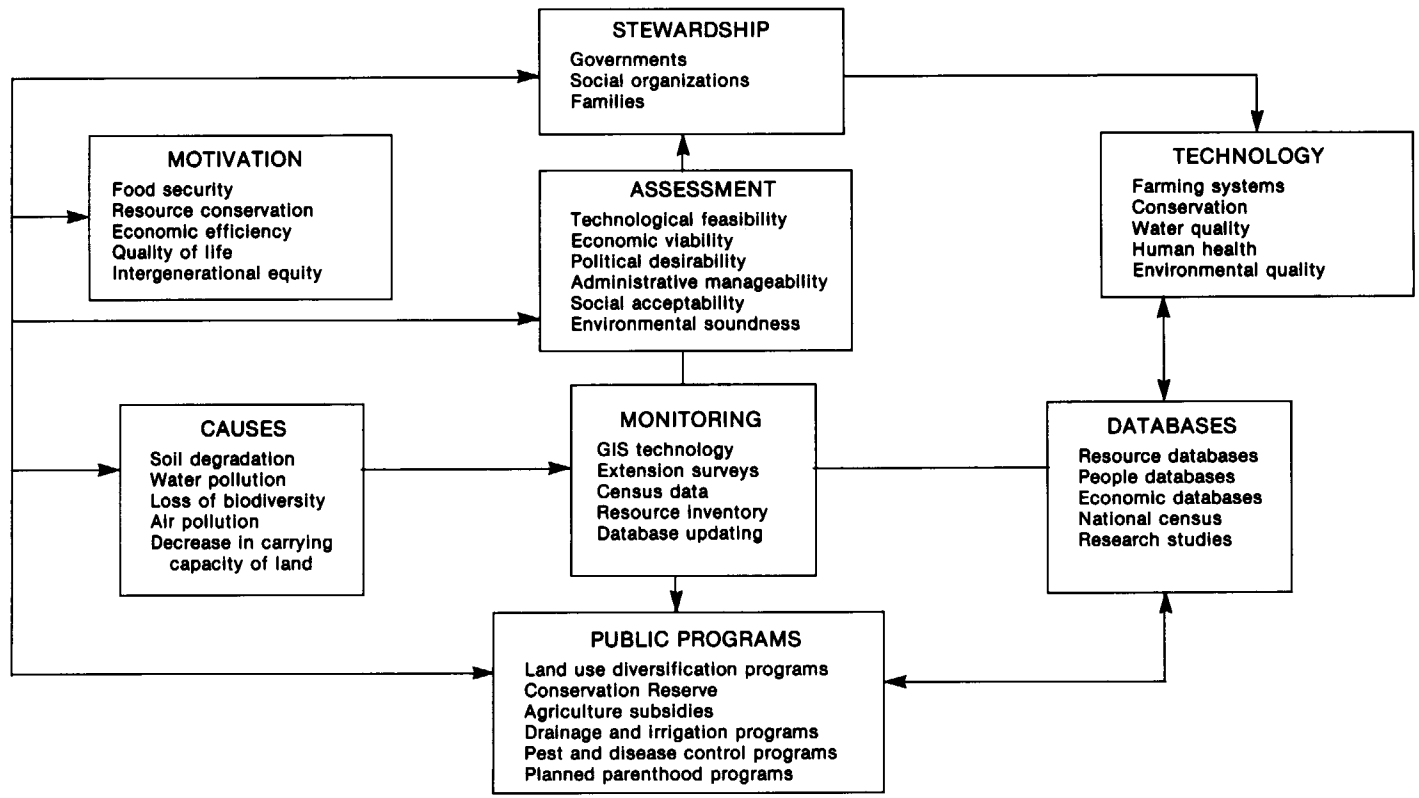

Fig. 2-1. A flow chart for attaining sustainability agriculture.

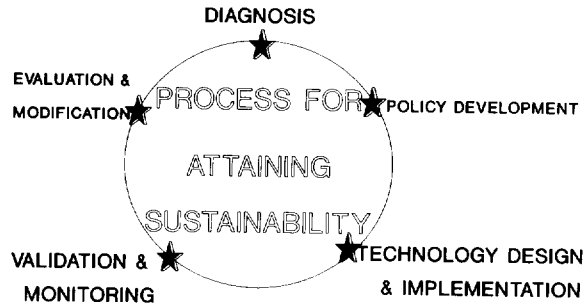

Fig. 2-2. Iterative process for attaining sustainability.

significant than the other. To attain some or all of these objectives in a sustainable manner, technologies are needed and each technology can be assessed (Virmani & Eswaran, 1989, 1990) to evaluate its appropriateness. In order to improve or introduce new technologies, a clear understanding of the causes of unsustainability is required and this is achieved through monitoring and development of relational data bases (Fig. 2-1). Based on such an assessment, public programs are launched.

This process for attaining sustainability is summarized in Fig. 2-2 and the sequence of iteration activities can be applied at any level, from the farm to a country or larger. Sustainable agriculture requires a slow stepwise approach commencing with a diagnosis stage where the system is critically evaluated for unsustainability. Figure 2-2 also can be used for designing research programs.

INDICATORS OF UNSUSTAINABILITY

Although there is a general consensus on the basic concepts of sustainability, measurement of sustainability is the immediate challenge. As indicated by Lynam and Herdt (1988), unless it is quantified, it will not be possible to evaluate a system, and consequently it wil not be possible to recommend remedial measures. Several kinds of indicators are needed, some of which are quantitative while others are qualitative. The latter, though not easily amenable to rigorous statistical analysis, are equally useful as they provide a first appraisal of the system.

The visible indicators of unsustainability are site-specific but, if available for defined ecosystems, become valuable tools particularly for extension workers. Jodha (1989) has developed a preliminary list of such indicators and this is excerpted in Table 2-1. Jodha (1989) working in the mountain areas of Asia, reports, "a persistent decline in crop yields in many areas. Mining activities have destroyed mountain flora, caused landslides, and choked water channels. In Tibet and Pakistan, highland pastures are overgrazed. High potential grazing areas are disappearing and cattle are being replaced by small ruminants.... The increasing scarcity of fuel and fodder is reflected in the longer distances and time involved in collection. Finally

Table 2-1 Negative changes as indicators of unsustainability.

	Changes related to	
Types of changes	Resource base	Resource use
Directly visible	Increased land slides and other forms of land degradation Abandonment of terraces Reduction in per capita availability of land Increased fragmentation of land holdings Changes in genetic composition of forest/pasture Reduction in water flows for irrigation and domestic use	Reduction in the intensity of crop rotation and other management practices Extension of cultivation to marginal lands Replacement of social sanctions for resource use by legal measures
Changes in response to resource degradation	Substitution of big animals with small animals: cattle with goats Change from deep rooted crops to shallow rooted crops Shifts in use of external inputs, from local manures to fertilizers	Unbalanced and high intensity of external input use Increased specialization in monocropping
Potentially negative changes due to development interventions	Introduction of new production systems without linkages to other diversified activities Promoting excessive dependence on outside resource, subsidies Ignoring traditional adaptive experiences Research and development focus on crops rather than resource	Ignoring ecosystem characteristics in designing programs and policies for area development Neglect of local wisdom and skills and excessive dependance on external expertise

there is an increasing dependence of people on government subsidies and inferior options." Jodha recommends that a reversal of the negative trends should be the primary focus of agricultural development strategies in mountain areas. This recommendation is applicable to most tropical ecosystems.

Quantified approaches are currently only available for a few components of systems. *There is an urgent need to develop methodologies that will provide reliable assessments of sustainability or unsustainability.* One of the greatest handicaps is the lack of data over a long time frame and methodologies to evaluate such data. Many agronomic experiments are conducted for 2 to 3 yr. The period of the research may be during a time when climatic conditions were favorable or a period of severe moisture stress or some situation in between. Agronomic research is seldom evaluated in this context of sustainability.

It is frequently necessary to evaluate the resource base itself for sustainability. This would permit the discriminatory use of the soil resources. Using simulated crop yields for different soils, Dumanski and Onofrei (1990) illustrated the different potential productivity of soils.

The previous examples only illustrate assessment of components of systems. There are other components such as soil loss, soil degradation, and biodiversity which are more difficult to quantify. The thrust of research in

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Table 2-2. Constraints and related issues of sustainable agriculture in developing countries.

Soil Related
Erosion and soil loss—watershed management
Salinity and alkalinity
Waterlogging
Soil acidity
Degraded lands
Pest and disease management
Balance between pest population and acceptable crop loss
Forestry and agroforestry
Changes in C cycle as a result of deforestation
Biodiversity and gene pool
Wildlife habitat
Quality of life of forest-based communities
Rangeland
Desertification
Animal supporting capacities
Biodiversity/biological resource conservation
Animal nutrition
Human nutrition
Population supporting capacities of semi-arid tropics
Food supply and security
Water resource demands
Water quality
Competition from agriculture, human,a nd industrial demands
Institutional
Framework/operational
Implications in legal, social, economic, and political
Stewardship—decision makers, private sector, families
Education and awareness
Technological
Human and physical resources
Training
Appropriateness, acceptability
Data bases, monitoring
Equity
Worst year—period of survival
Best year—amortization of benefits with time (response farming?)

the near future must be towards a quantification of sustainable land-use systems.

CONSTRAINTS

Developing countries have several constraints summarized in Table 2-2, not only in attaining sustainability but even to increase the production of their agriculture. Kellogg (1967) stated that he,

> . . . fully expects that 'some day' the most productive agriculture of the world will be mostly in the tropics, especially in the humid parts. . . Whether 'some day' is 25, 50, 100, or some other number of years from now, depends on how

Table 2-3. Chemical constraints in Africa (FAO, 1986).

Chemical constraints	Area	
	millions ha	%
Low CEC	1 295.5	45.6
Al toxicity	635.0	22.3
P fixation	382.5	13.5
Low K supply	637.0	22.4
Salinity	75.6	2.7
Alkalinity	31.0	1.1

> rapidly institutions for education, research, and the other public and private sectors of agriculture will develop.

Today, more than 20 yr after this statement was made, "some day" may have arrived at some plantations and a few other areas. For the most part of the tropics, however, "some day" remains a futuristic fantasy rather than a realistic scenario. Small-scale farming prevails in most of the region and, as Lal (1987) has pointed out,

> the subsistence farmer who faces famine would consider a successful technology to be the one that produces some yield in the worst year rather than one that produces a high yield in the best.

The constraints in Africa are perhaps more urgent than the other continents. About 47% of Africa is dry and in these regions apart from some nomadic grazing, there is no potential for agriculture in the absence of massive capital investment. About 19% of the continent has a semiarid climate which is characterized by unreliable and low rainfall keeping agriculture at the mercy of the rain. Although moisture stress is not a major constraint in the remaining part of Africa, pests and diseases, and many soil-related factors (Table 2-3) keep agriculture at marginal levels. Steep slopes, sandy textures and other specific management problems also prevent a productive agriculture in large areas of Africa. Similar situations prevail in Asia and South America.

Table 2-4 lists the extent of degraded land in Asia and it is evident that it is of alarming proportions. Rehabilitation of degraded lands is an immediate necessity even prior to considerations of sustainable agriculture on such lands.

The introduction of high-yielding varieties of rice (*Oryza sativa*), wheat (*Triticum aestivum*), and to a lesser extent other grain crops, which signaled the dawn of the Green Revolution, also has introduced or resulted in a number of problems. A major impact has been the loss of genetic resources of land races of major crops. These natural varieties evolved through time and space and their losses are permanent (Singh, 1989). Monoculture, coupled with the use of pesticides, has other drawbacks as evidenced by the spread of rice brown plant hopper (*Landelphax striatellus*) in Asia. Even the multiple resistant IR36 was subject to pest damage under monocropping in Indonesia in 1986. The pesticides apparently eliminated the natural enemies of the plant hopper resulting in an imbalance of the biosystem.

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Table 2-4. Estimated extent of degraded land (km^2) for selected countries in Asia-Pacific. Parenthesis indicates percentage of respective land area to total area (Dent, 1990, unpublished data).

Country	Total land area	Arable & cropped land area	Degraded land area
Bangladesh	13 391	9 164 (68)	989 (7)
China	932 641	96 976 (10)	280 000 (30)
India	297 319	168 990 (57)	148 100 (50)
Indonesia	181 157	21 220 (12)	43 000 (24)
Laos	23 080	901 (4)	8 100 (35)
Myanmar	65 754	10 000 (15)	210 (3)
Pakistan	77 088	20 760 (27)	15 500 (17)
Philippines	29 817	7 930 (27)	5 000 (17)
Western Samoa	283	122 (43)	32 (11)
Sri Lanka	6 474	1 887 (29)	700 (11)
Thailand	51 089	20 050 (39)	17 200 (34)
Tonga	72	48 (67)	3 (4)
Vietnam	32 536	6 470 (20)	15 900 (50)

Expanding population and the demand for agricultural land has denuded many countries of natural vegetation. The consequence has been erosion, loss of biodiversity, and a general decrease in the agricultural production as a whole. Increasing use of pesticides and herbicides is beginning to have consequences similar to those in many western countries. Pollution of the ecosystem is not the only problem. As shown earlier with the case of the rice plant hopper, an imbalance in the natural food chain is created.

Other constraints are listed in Table 2-2. Each country would have some or many of these constraints and a major problem is that there is little information on the kinds of constraints and their extent and magnitude in many countries.

Soil Resource-related Constraints

The soil qualities important for sustainable agriculture (Eswaran & Virmani, 1990) are many but can be reduced to 10: (i) Available water-holding capacity; (ii) nutrient retention capacity—cation exchange capacity; (iii) nutrient availability—pH and base saturation, P and K; (iv) nutrient fixation; (v) chemical constraints—acidity, sodicity, salinity; (vi) physical constraints—low hydraulic conductivity, permeability, high bulk density, crusting; (vii) effective soil volume—depth to root restricting layer, stoniness, structure; (viii) surface tilth; (ix) erodibility; and (x) water-logging.

In Table 2-5a,b,c,d, the soil qualities listed previously which are major determinants of sustainability are provided for four selected soil orders in soil taxonomy. These four soils together occupy about 60% of the total land surface in the Tropics. Similar tables may be constructed, and with greater degree of reliability, for the lower categories, such as subgroups, families, or even soil series. Eswaran (1977, p. 289-314) has developed similar tables of determinants for the subgroup category for a few orders of soils. Based on the determinants, "Sustainable Agriculture Success" in Table 2-5 attempts

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Table 2-5a. Information on Oxisols.

Soils	Soil moisture regimes		
	Aridic	Ustic/Xeric	Udic
Oxisols			
Area			
World (millions sq. km)	0.01	4.2	7.7
Countries	USA	Brazil, Zaire Zambia, Kenya Uganda, Nigeria	Indonesia Malaysia Zaire
Population density			
Current		•†	••
Potential		••	••••
Population supporting capacity			
Low input		•	••
Medium input		•	•••
High input		•	•••••
Constraints-soil qualities			
Water holding capacity		•••••	•••••
Nutrient retention Capacity		•••••	•••••
Nutrient availability		•••••	•••••
Nutrient fixation (P)		••••	••••
Chemical constraints		•••	••••
Physical constraints		••••	••
Effective soil volume		•	•
Surface tilth		•	•
Erodibility		•••	•
Waterlogging		•	•
Management options			
Shifting cultivation		•••••	•••••
Annuals		•	•
Perennials		••	•••••
Agroforestry		•••••	•
Forestry		•••••	••••
Nutrient		•••••	•••••
Pests		•••	••••
Weeds		••••	•••••
Sustainable agriculture success			
Low input		•	•
Medium input		•	••
High input		••	••••

† Dot indicates relative importance to sustainability: • very low to ••••• very high.

to list the possibility of attaining sustainable agriculture under low-, medium- and high-input technologies.

Eswaran and Virmani (1990) have indicated the need to establish standards for threshold values, with respect to specific uses, for each of the soil qualities. The USDA-SCS has established the soil loss tolerance "T value" as a kind of soil quality standard. This standard is used to determine if a practice or sets of practices are essential to meet resource management needs.

Until and unless such soil quality standards are established, it will be difficult to monitor soil degradation and consequently the effects of management. From the point of view of sustainable agriculture, soil quality standards provide a basis to evaluate changes in soil conditions due to management, provide the tools for monitoring changes, provide the basis

Table 2-5b. Information on Ultisols.

Soils	Soil moisture regimes	
	Ustic/Xeric	Udic
Ultisols		
Area		
World (millions sq. km)	4.5	6.0
Countries	Kenya, Columbia, India Zaire, Ghana, Nicaragua	Malaysia, Thailand Cameroon, Panama Costa Rica
Population density		
Current	•••†	••••
Potential	••••	•••••
Population supporting capacity		
Low input	•	••
Medium input	••	•••
High input	••••	••••••
Constraints-soil qualities		
Water holding capacity	•••••	••••
Nutrient retention Capacity	•••	••
Nutrient availability	•••	••
Nutrient fixation (P)	••	•••
Chemical constraints	••	••••
Physical constraints	•••	••
Effective soil volume	••••	••••
Surface tilth	•••••	•••••
Erodibility	••••	•••
Waterlogging	•	••
Management options		
Shifting cultivation	••	•
Annuals	••	•
Perennials	•••	•••••
Agroforestry	•••••	•••
Forestry	•••••	•••••
Nutrient	•••••	•••••
Pests	•••	•••••
Weeds	••••	••••
Sustainable agriculture success		
Low input	•	•
Medium input	••	•••
High input	•••	•••••

† Dot indicates relative importance to sustainability: • very low to ••••• very high.

for legislation for soil stewardship, provide a means of signaling potential problems in order to trigger research or development activities, and provide the criteria for evaluating sustainable agriculture.

There is an urgent need for the international scientific community, in collaboration with potential users, to develop guidelines for these standards. As the socioeconomic conditions vary, each country would probably need its own set of standards.

Detailed soil maps of countries would show the areas with major resource constraints and management options may be selected accordingly. An assessment of the success of sustainable agriculture purely from the point of view of soils, also is given in Table 2-5,a,b,c,d of the four soils, the Alfisols have fewer limitations and thus have a higher probability of attaining sus-

Table 2-5c. Information on Vertisols.

Soils	Soil moisture regimes		
	Aridic	Ustic/Xeric	Udic
Vertisols			
Area			
World (millions sq. km)	1.1	1.8	0.05
Countries	Sudan	Sudan, India Australia	Indonesia Uruguay
Population density			
Current	•†	••	•••
Potential	•	•••	•••••
Population supporting capacity			
Low input	•	••	•••
Medium input	•	•••	••••
High input	••	••••	•••••
Constraints-soil qualities			
Water holding capacity	•••••	•••••	•••••
Nutrient retention Capacity	•••••	•••••	•••••
Nutrient availability	•••••	•••••	•••••
Nutrient fixation (P)	•••	••••	•
Chemical constraints	•••••	•••	••
Physical constraints	•••••	•••••	•••••
Effective soil volume	•	•	•
Surface tilth	•••••	•••••	•••••
Erodibility	•••••	•••••	•••••
Waterlogging	•••••	•••••	•••••
Management options			
Shifting cultivation	•	•	•
Annuals	•	••	•••
Perennials	•	•••	••••
Agroforestry	•	•••	••••
Forestry	•	•••	••••
Nutrient	•	•••	••••
Pests	•	•••	••••
Weeds	•	•••	••••
Sustainable agriculture success			
Low input	•	••	•••
Medium input	•	•••	••••
High input	•	••••	•••••

† Dot indicates relative importance to sustainability: • very low to ••••• very high.

tainability even under low-input systems. The Oxisols and Ultisols on the other hand, due to their intrinsic properties behave and respond differently.

Detailed soil maps are needed to design appropriate farming systems, target soil conservation measures, recommend fertilizer policy and monitor nutrient and other needs of the farmer, and make efficient utilization of the extension services.

For a country to adopt a policy of sustainable agriculture and implement this policy, soil resource inventories at several scales are needed. At the national level, there must be an inventory of the Major Land Resource Areas (MLRA). The MLRA maps are used at national level (i) as a basis for making decisions about agricultural issues; (ii) as a framework for organizing and conducting resource conservation programs; (iii) for geographic

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Table 2-5d. Information on Alfisols.

Soils	Ustic/Xeric	Udic
Alfisols		
Area		
World (millions sq. km)	9.5	7.6
Countries	<---------- In most countries	---------->
Population density		
Current	••••†	••••
Potential	•••••	•••••
Population supporting capacity		
Low input	•••	••••
Medium input	••••	••••
High input	•••••	•••••
Constraints-soil qualities		
Water holding capacity	•••••	•••••
Nutrient retention Capacity	•••••	•••••
Nutrient availability	•••••	•••••
Nutrient fixation (P)	•	•
Chemical constraints	•	•
Physical constraints	•	•
Effective soil volume	•••••	•••••
Surface tilth	•••••	•••••
Erodibility	••••	•••
Waterlogging	•	•
Management options		
Shifting cultivation	•••	••••
Annuals	•••••	••••
Perennials	•••	•••••
Agroforestry	•••••	••••
Forestry	••	•••
Nutrient	•	••
Pests	•••	••••
Weeds	•••	••••
Sustainable agriculture success		
Low input	••••	••••
Medium input	•••••	•••••
High input	•••••	•••••

† Dot indicates relative importance to sustainability: • very low to ••••• very high.

organization of research and conservation needs and the data from these activities; (iv) for coordinating technical guides among states and districts of a nation and among countries; (v) for organizing, displaying, and using data in physical resource inventories; and (vi) to aggregate natural resource data.

The MLRAs are most important for agricultural planning and have value for interstate, regional, and national planning and are most important tools for targeting sustainable farming systems technology. An assessment of the sustainability of agriculture for each of the MLRA units can be determined to guide national planning.

Soil resource inventories at intermediate scales between the MLRA map and farm level maps may be made if time, personnel, facilities and funds permit. In most less developed countries (LDCs) this is not the case and so emphasis must be on the farm-level maps. Farm-level maps are expensive to make and require highly trained personnel. There must be a national in-

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stitution to coordinate the effort and develop and provide the standards for evaluation. In most LDCs, soil surveys are done on contract and by expatriates. Standards, methodology, and criteria all vary and few of these maps have long-term use. In addition to making maps, the extension service and decision makers must be trained to use the maps. The national institution must provide basic soil services to backstop potential users. These are some of the ingredients necessary for achieving sustainable agriculture.

There is practically no developing country in the world which has a program of systematic soil surveys at this scale and this is the major obstacle to developing the prerequisities for sustainable agriculture in these countries.

Constraints to Implementing Sustainable Agriculture

The efforts to improve the productivity of subsistence farming are just beginning to get the attention of the national and international agricultural research centers. Emerging technologies such as agroforestry, alley and multiple cropping, improved genetic material, N-fixing trees and crops, and biotechnology hold much promise. In the context of this paper, it also should be mentioned that it would be advantageous if the new farming systems developed are robust enough to be insensitive to the field-scale soil microvariability that tends to exist on tropical farms.

There are several constraints which prevent or hinder developing countries from being more receptive or even adopting sustainable agriculture. The overriding constraint is perhaps the absence of economic incentives. This transcends all levels from the government policy making level to that of the farmer. Reduction in soil loss and long-term environmental degradation are not tangible reasons for the small farmer whose immediate concerns are providing food for the family and assuring the quality of life in the immediate future. The farmer is aware and will contribute to the progress of his society. A good example is the success of social forestry in India. However, the farmer's contribution is extracurricular with the family concerns being the first priority.

Even if the farmer is willing and able, in most developing countries, extension services are poor or nonexistent. Creating an awareness among farmers is frequently an ad hoc exercise or absent. Lack of awareness, not only at the farm level but also at higher levels in the society is a second constraint in many developing countries.

The third major constraint relates to stewardship. No system becomes operational if it is not institutionalized. In many developing countries, particularly in Africa, research and development in agriculture including extension services are poor and suffer from lack of trained personnel, facilities, and motivation. In many African countries, donor-supported research is still the rule and in this environment, the country cannot build a research tradition and local expertise and consequently the benefits are project specific.

The fourth constraint relates to the information base. Implementing sustainable agriculture assumes that (i) reasons for unsustainability are known, (ii) there is sufficient information on the resource base to target sustainabili-

ty related activities, and (iii) the resource base has been monitored to evaluate sustainability. In practically all developing countries, these three statements are false. In the past three decades or more, international donors supporting agricultural research and development focused on improving the genetic potential of the crop and related management practices to improve yields—a spin-off of the Green Revolution. There is practically no developing country with a systematic detailed soil resource inventory program. Agronomic research, including those by western expatriates, have been conducted and are still being conducted on soils for which they know nothing about. The so-called outreach research on farmers fields conducted by the Consultative Group on International Agricultural Research (CGIAR) institutions has many limitations, as few of the external variables that affect crop performance are monitored. In the absence of information on the resource base, it would be a waste of time and effort to institute sustainable agriculture.

A fifth constraint to implementing sustainable agriculture relates to research. Research methodology is not available and, until recently, not even the basic principles and concepts have been enunciated. Fundamental questions such as how long should an experiment be conducted, what are the treatments, what are the measurements, and how can the data be analyzed, have yet to be answered.

Challenges to Instituting Sustainable Agriculture in Less Developed Countries

There are many hurdles to overcome before a significant number of developing countries have sustainable agriculture programs in place. The responsibilities rest not only with the countries themselves but also with the international community, particularly donor countries. The basic question is how to incorporate a sustainability component in research and development programs.

Role of Donor Agencies

Donor agencies must make an unequivocal commitment towards a long-term support for sustainable agriculture. Many national leaders of developing countries. They view this as an "alka-seltzer" syndrome, where excitement and enthusiasm bubble up only to fizzle out within a short period. This image must be erased.

Over the last five or more years there has been a sufficient number of meetings, workshops, and symposia addressing the subject. It is now time to synthesize the subject and develop action plans for assistance. There is a tendency for many donor supported projects to give a "sustainability twist" to ongoing projects. In the long run this is a disservice and would lead to credibility problems.

From a research point of view, there is a need for a task force to evaluate not only the research needs but also to evaluate research methodologies. The

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projects must be multidisciplinary and the approach must have a broader context than conventional on-farm research. The area under consideration would be some kind of land unit, such as a catchment or watershed or a defined agro-ecological unit. The purpose of the research, apart from alleviating the low socioeconomic status of the farms will in addition enhance the quality of the resource base and minimize the environmental degradation processes. Consequently, monitoring the resources becomes an important component of any sustainable agriculture research project and methodologies for this must be developed. Funds must be committed so that the research is conducted over a sufficient time period, usually of the order of 10 or more years.

As sustainable agriculture cannot be achieved overnight, an important component of developmental assistance programs is institution building. Many developing countries still do not have detailed information on the resource base. Data bases must be developed, and techniques to monitor the resource must be instituted. This requires a cadre of highly trained professionals supported with adequate facilites.

An equally important contribution of developmental assistance programs is assistance in creating awareness. Nongovernmental organizations (NGO) are generally equipped to provide such services but require funds to cary out their activities. A casual evaluation shows that the impact of NGO activity is frequently greater and that they have more interaction with or influence on the rural community than their government counterparts. Sustainable agriculture would require NGO participation for greater impact.

CHOICES

Sustainable agriculture is not an option, it must be the goal of all developing countries. It must be viewed as a challenge and a motivating force to guide our research and development efforts in the foreseeable future.

The challenge of enhancing productivity while maintaining environmental soundness and attaining intergenerational equity is a new challenge for the low-input, resource-poor farmers of developing countries. Sustainable agriculture calls for an education of the farmers particularly on the long-term consequences of their traditional methods of agriculture. They must be assisted with innovative appropriate methodologies. They also must be provided with incentives to undertake this new thrust.

The application of the tenets of sustainable agriculture necessitates new thrusts in research, development, and implementation. The former demands innovative approaches and international collaboration in a network mode, while the latter requires institutional development, awareness at all levels, and socioeconomic motivation. A dedicated stewardship is the first step in the process of attaining sustainable agriculture. There must be a commitment at the highest levels of government and this must be coupled with an action program that addresses the needs of the farmer in the context of the environment.

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In the absence of massive donor support, sustainable agriculture in developing countries becomes untenable in the immediate future. Donors must consider this as an investment to assure food security and social stability in the world. The impact of sustainability also can be used as a mechanism to evaluate project proposals and/or to evaluate ongoing projects. This may be one mechanism to introduce sustainability in all agricultural research and development projects.

In conclusion, the alternative to sustainable agriculture is degradation of the resource base, loss of biodiversity, environmental pollution, reduction of the population supporting capacity for humans or animals, and a general decrease in the quality of life for all living things on this planet. The choice is apparent, we have an obligation to move in this direction.

As the world will eventually have to feed 10 billion people, much of the as-yet underutilized land in the tropics will have to be brought under cultivation. Can there be sustainable agriculture on these lands? The four basic causes of land degradation—overgrazing on rangeland, overcultivation of cropland, waterlogging and salinization of irrigated land, and deforestation—all result from poor management of the land and can, therefore, at least in principle, be controlled. The record to date, however, is quite poor. Although effective technologies that prevent or reduce land degradation either exist or are being developed (Postel, 1989), their application is still constrained by institutional and societal barriers. The problem is aggravated by the fact that degradation control crosses all traditional boundaries and that lasting solutions must be rooted as much in social and economic reforms as in effective technologies (Postel, 1989). In the Tropics, as elsewhere, the current prospects for institutionalizing sustainable development strategies are not very encouraging. Only with massive developmental assistance can this situation be redeemed.

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