PN ABX-329
ISN 92303

The Soil Management Collaborative Research Support Program

Management Entity Office
Box 7113, North Carolina State University
Raleigh, NC 27695-7113 USA • CGNET: TropSoils
Phone (919) 515-3922 • FAX (919) 515-3942
Email: Roger_Hanson@NCSU.EDU

January 18, 1995

Document Acquisitions
POL/CDIE/DI
Room 303 SA-18
Agency for International Development
Washington DC 20523-1803

ATT: Referred Publications supported by Project No. 9311311, Soil Management Collaborative Research Support Program Under Grant No. DAN-1311-G-00-1049-00

Enclosed are two (2) copies of two (2) technical publications from the Soil Management Collaborative Research Support Program, Project No. 9311311, under Grant No. DAN-1311-G-00-1049-00.

Sincerely,

Roger G. Hanson

RGH:sm

Enclosures

LAND DEGRADATION AND SUSTAINABLE AGRICULTURE: A GLOBAL PERSPECTIVE

Hari Eswaran and Julian Dumanski

World Soil Resources, USDA Soil Conservation Service, P.O. Box 2890, Washington DC, 20013, USA, and Center for Land and Biological Resources Research, Agriculture and Agrifood Canada, Ottawa, Canada, respectively

Paper presented at the

8th International Soil Conservation Conference

December 4-8, 1994

New Delhi, India

LAND DEGRADATION AND SUSTAINABLE AGRICULTURE: A GLOBAL PERSPECTIVE

Hari Eswaran and Julian Dumanski

World Soil Resources, USDA Soil Conservation Service, P.O. Box 2890, Washington DC, 20013, USA, and Center for Land and Biological Resources Research, Agriculture and Agrifood Canada, Ottawa, Canada, respectively

Abstract

The Bruntland Commission and AGENDA 21 of the United Nations Conference on Environment and Development have emphasized the need to control the degradation of the resource base. Attention is shifting towards enhancing the quality of the environment and away from agricultural research and national food security. In the past, agriculture and environment were considered as separate and independent areas of research, but the new paradigm requires a complementarity of effort. Experience has shown that agriculture can cause environmental problems but if properly planned and managed, agriculture becomes an environmental solution. In this paper we develop the theme of an 'ecosystem based agriculture' and emphasize that agricultural research and development can be part of the solution to environmental problems, if the focus is cc :t and emphasis is on sustainability.

Understanding land resource systems includir~ the functions and interactions of each of the components is conditio sine qua non to sustainable land management and to reducing land degradation. The key to intergenerational equity, enhancing economic growth, and assuring sustainability depends on three interrelated facts:

1. *Land degradation results from mismanagement of land and thus deals with two interacting systems, the natural ecosystem and the human, social system.*
2. *In developing countries, land degradation will be controlled only when the agricultural sector is strengthened and progress is made towards food security.*
3. *Until all levels of the decision making process are cognizant of these facts, unabated land degradation will continue.*

A better understanding of the degradation process and the resilience characteristics of the resource base coupled to improved soil, water and nutrient management is necessary to meet the global challenges of sustained crop production in harmony with good environmental management. This is the challenge and the new agenda for research and development in the immediate future. The ecosystem approach is the key to reducing degradation and ensuring sustainability of agriculture.

LAND DEGRADATION AND SUSTAINABLE AGRICULTURE:

A GLOBAL PERSPECTIVE

Hari Eswaran and Julian Dumanski

World Soil Resources, USDA Soil Conservation Service, P.O. Box 2890, Washington DC, 20013, USA, and Center for Land and Biological Resources Research, Agriculture and Agrifood Canada, Ottawa, Canada, respectively

INTRODUCTION

Sustaining the productivity of soil and water resources into the next century is an important global and national problem. This will require scientists to translate their knowledge and experience into implementable policy decisions. There is increasing evidence that in many countries, bo in developed and developing countries, large of arable land are inadequately managed for long-term sustained production (FAO, 1993). In addition, pressures on land are rapidly increasing due to ever increasing populations competing for finite land resources. Forest lands are being lost to agriculture; agriculture lands are being lost to urbanization and other uses. Simultaneously, there is increasing cognizance and demand by society for more land to be set aside for recreation, wildlife preserves, and maintenance of biodiversity. Today there is enhanced environmental awareness requiring a more controlled use of inputs to increase agricultural production while limiting the degradation and pollution of soil and water resources.

In a recent study, Pimental, et al, (1994) posed the question, "Does society want 10 to 15 billion humans living in poverty and malnourishment or 1 to 2 billion living with abundant resources and a quality environment?" Evaluating the available land, water and energy resources, they conclude that for a quality life (probably similar to the one currently in the U.S. or Canada), an ideal world population is about 2 billion people. One could argue the concept of a 'quality life' and their analysis, but nevertheless, it points to the fact that a manageable global population is probably at about current levels. Land degradation is contributing to crop yield declines and Buringh (1989) estimated a 15 to 30% decline in world food production over a 25 year period due to degradation. Based on global grain production, the impact of this level of degradation is about 100 billion dollars annually.

Thus the paradigm for agriculture, during the decades of the sixties and seventies, to meet the challenges of increased food and fiber production must change to one of sustainability and respect for natural resources. Stewardship for natural resources (Ruttan, 1987) has emerged as critical for human welfare, and this calls for a new agenda [illegible] use and management of all natural resources and specifically, the land resources. In this context, land degradation is a major concern requiring more reliable assessment and monitoring, and cost- ffective technologies for mitigation and rehabilitation of degraded lands (FAO, 1989; Hudgens, 1992).

Land degradation results from mismanagement of land, and thus is highly related to two interacting systems, the natural ecosystem and the human, social system. Interactions between these systems determine the success or failure of resource management programs. To mitigate the continuing impact of land degradation on economic development, the following principles are relevant:

a. environment and agriculture are intrinsically linked and research and development must address both; sustainable land management techniques reduce pressures on the land, particularly on fragile lands;

b. land degradation is as much a socioeconomic problem as it is a biophysical problem;

c. land degradation, economic growth, and poverty are intractably linked (people living in the lower part of the poverty spiral are in a weak position to provide the necessary stewardship and are prone to degrade the resource base. As a consequence they move further down the poverty spiral, inducing more degradation and setting the vicious cycle in motion); on the other hand, economic growth by itself is not a guarantee against land degradation unless profits are reinvested to maintain the quality of the land;

d. implementation of mitigation research to manage degradation can only succeed if land users have control and commitment to maintaining the quality of the resources;

e. agricultural research focus must shift from increasing productivity to enhancing sustainability recognizing that agriculture can be an important solution to environmental management;

f. land use must match land quality; appropriate national policies must be implemented to ensure that land uses are not out of balance with environmental potentials;

Dumanski and Smyth, (1994) summarize the main issues impacting sustainable agriculture from a land resource point of view as:

- finite supply of land suitable for agriculture;

- impacts of rapidly rising population

- impacts of land and soil degradation

- impacts of changing land use on global environment

- impacts of changing land use on genetic diversity

These issues are not new but they take on an urgency never before felt in human history. This paper restates some of the concerns to emphasize the magnitude and crucial nature of the problem. We also speculate why, despite awareness at the highest decision making levels, there is little done to rectify the situation. Finally, we look at international efforts to promote integrated approaches to minimize land degradation and some research and development needs.

THE GLOBAL DIMENSION OF LAND DEGRADATION

The Food and Agriculture Organization defined land (FAO, 1976) as:

"an area of the earth's surface, the characteristics of which embrace all reasonably stable, or predictably cyclic, attributes of the biosphere vertically above and below this area including those of the atmosphere, the soil and underlying geology, the hydrology, the plant and animal populations, and the results of past and present human activity, to the extent that these attributes exert a significant influence on present and future uses of the land by man."

The Journal of Land Degradation and Rehabilitation defines **land degradation "as the loss of utility or potential utility through reduction of or damage to physical, social or economic features and/or reduction of ecosystem diversity."** Land degradation is a major threat to development, and the Brundtland Commission (WCED, 1987) noted that "there is a growing realization in national and multinational institutions that not only do many forms of economic development erode the environmental resources upon which they are based, but at the same time environmental degradation can undermine economic development."

In an effort to establish baseline data about the state of land degradation, the United Nations Environment Programme (UNEP) commissioned the International Soil Reference and Information Center (ISRIC) to initiate a project entitled Global Assessment of Soil Degradation -- GLASOD -- (Oldeman et al., 1990). The project recently published a World Map of the Status of Human-induced Soil Degradation. According to the explanatory note that accompanies the maps, the percentage of land affected by soil degradation is as follows:

Africa............	17%
Asia..............	18%
South America.....	14%
Central America...	21%
Australasia.......	[illegible]%
WORLD..........	**15%**

The GLASOD project arrived at these estimates by evaluating land resources and degradation resulting from water erosion, wind erosion, chemical deterioration, and physical deterioration (tables 1, 2, 3). It differentiates four degrees of degradation (slight, moderate, strong, and extreme) and indicates the causative factors (deforestation, overgrazing, mismanagement, overexploitation, and bioindustrial activities). At the scale of 1:10 M, the assessments are necessarily broad, but constitute a first step towards a global evaluation of the nature and geographical extent of land degradation.

In a recent assessment of the Food and Agricultural Organization (FAO, 1994, unpublished communication), up to 140 million hectares of fertile land (an area the size of Alaska) are expected to become seriously degraded over the next 20 years.

FAO also states that about 305 million hectares of land (the size of Western Europe) is already seriously degraded and about 910 million hectares (size of Australia) is moderately degraded. Of the total global land mass, only about 11% has few or no limitations to agriculture and a significant part of this is in the temperate regions of the world where climatic conditions are also favorable for high production. In contrast the tropical zones with much higher populations have poorer soil resources (Dent, 1990) with lower tolerances for abuse and lower resilience to recover from degradation. Land degradation, with serious food security and sustainability consequences, is increasingly recognized as a major threat to third world countries.

The FAO, UNEP, and ISRIC studies have shown that the three main causes of land degradation are overgrazing, destructive agricultural practices and deforestation. Overgrazing accounts for about 35% of all degradation but mismanagement of agricultural land acc[illegible] for 27% of the degradation. In western countries, [illegible] largely results from capital-int[illegible]sive practices while in third world countries, cultivation of steeplands and absence of residue management practices are the major causes. Population pressures result in [illegible] of fragile ecosystems such as steeplands and wetlands. In both cases, apart from the consequent destruction of the resource base, biodiversity is reduced and natural habitats are destroyed. It is estimated that about 150 mi[illegible]on hectares of forests were cleared in the decade of the eighties for agriculture and other uses. Deforestation and drainage of wetlands not only permanently alters the quality of the soil resource but, in addition, changes the nature of the ecosystem and also impacts the ecosystem of the hinterland.

NATURAL RESOURCE CONSIDERATIONS

The use of land resources for agriculture (Table 4) is related to land quality and supply, and capacity of the land of differing quality to respond to management. Global demand for food is expected to more than double by the year 2030 and this would place considerable pressures on land resources. Dudal et al, (1982) estimate that globally there are about 3 billion hectares of potential cropland of which 1.5 billion hectares are already cultivated. These are the most suitable for cultivation, the remainder being marginal and used generally for grazing and other extensive uses. About 87% of the uncultivated land is in the tropics, with many serious constraints to continued use.

The land resource

Land quantity. Much of the land reserves are in Africa and South America with very small amounts in Asia where much of the population increase is expected to take place. The strategy of increased food production in Africa and S. America might involve some expansion into virgin lands, but in Asia increased intensification of land use is necessary to increase production. Even in Africa and S. America, major investments will be necessary to capture the potential of these lands for agriculture. In addition, the loss of biodiversity will have to be considered and this will effectively reduce the amount of potential cultivable land globally. Recent estimates based on economic and environmental considerations (Dumanski, 1994) suggests that potential increases in the amount of new land from present levels may not be more than 5%.

Apart from the physical availability of land, the desire to maintain an ecosystem balance will also place pressures on land use. The non-agricultural uses of land, specifically for forestry and biodiversity reserves will increase the pressure for increased productivity of currently cultivated land. There are large areas of fragile ecosystems, specifically steeplands and wetlands, which require protection and conservation. Agricultural creep in the form of shifting cultivation is a major environmental problem in many countries. At the other end of the spectrum urbanization of agricultural land is also becoming a problem in many developing countries.

<u>Land quality</u>. Although about 87% of the land available for cultivation resides in the tropics, this land is of poor quality compared to much of the land already under cultivation. Table 4, lists the major problems of soils with respect to their quality. The significance of the constraints is well documented in literature and it suffices to state that both the magnitude and kinds of constraints are different when compared to the temperate areas.

Not only is the inherent quality of the land in much of the tropics poorer than their temperate counterparts, the rates of degradation induced largely by misuse of the land is also higher. Figures la and lb, developed with data excerpted from Oldeman, et al, (1990) show the relative extent of the different forms of soil degradation. Degradation reduces the production capacity of the soil but to a minimal extent can be rectified by improved nutrient management. However, from an environmental point of view, there are various forms of degradation that must be reduced and this requires knowledge of the resilience capacity of the systems (Eswaran, 1993).

The Consultative Group on International Agricultural Research (CGIAR) and other international institutions promoted the Green Revolution, based mostly on plant breeding research, towards food production in the tropics. Although the resolve of this is not insignificant, it has not provided the extent of the benefits promised and also has, in many instances, resulted in increased land and environmental degradation. This approach has not lived up to expectations, due to the confounding effect of the quality of the land resources (coupled to the socioeconomic environment).

The water resource

Water, like land, is also a scarce resource in terms of availability as well as distribution. Over the past three decades, 30 to 40% of the food supplies of the world have been grown under irrigation. In AT 2010 (FAO, 1994), FAO states that, "Even though land constraints are severe in some countries and regions, those of freshwater supplies for agriculture are even more limiting for many more countries".

Though the quantity of water is the main issue in developing countries, the quality of water must also be considered (Table 4). The biggest challenge to agriculture is water use efficiency particularly in the arid and semi-arid parts of the world. Non-agricultural demand for water particularly urban demand, has emerged as a competitor for the limited water supply and this is most evident where there is intensive use of water for agriculture (e.g., in the United States). In semi-arid areas, resolution of the "politics" of water is the first priority towards attaining sustainability. Irrigated lands out-produce non-irrigated areas, but irrigation often precipitates a plethora of other environmental problems.

<u>Water quantity</u>. Water supply for agriculture is usually resolved through irrigation. About 253 million hectares of global cropland (17%) is irrigated and this produces about 30% of total food. The World Bank (1990) estimates that there is about 137 million hectares of potentially irrigable land, of which about 80% is in developing countries. However, these numbers are misleading because the costs of establishing irrigation schemes is beyond the means of most developing countries, the environmental impact of irrigating these lands is being

increasingly questioned, and the lack of maintenance of irrigation systems has reduced the economic life of many systems. Despite the warning of soil scientists many irrigation schemes do not include adequate drainage facilities, resulting in salinization and waterlogging of the land. The initial increased production of the irrigated land is slowly offset by the secondary problems leading to land abandonment. Irrigation management, particularly of the already degraded lands is a major concern.

In rain-fed agricultural areas, water use efficiency is a major problem requiring greatly improved land management technologies which often are knowledge intensive. A holistic approach, which includes nutrient management, pest and disease management, and soil conservation are used in these areas to ensure sustainable production.

<u>Water quality</u>. Problems of water quality take many forms (Table 4). The major concerns stem from the experiences of developed countries where nutrients and pesticides contaminate surface and groundwater because of poor monitoring and management. Water quality is also linked to sedimentation which is related to erosion. The benefits of erosion control are seen in not only the on-site crop performance but also the off-site quality of the water and the quality of the estuarine aquatic resources.
Saline and alkaline soils are endemic and often extensive in many semi-arid and arid lands. However, of recent concern (Fig. 1b) is that human induced salinization is pervasive in about 25% of all irrigated lands and is increasing. Neglect of the salinity and water logging problem by many countries is partly due to the fact that payoff to investments in drainage is long-term; however, costs of rehabilitation of saline and water-logged areas are much higher than prevention. This problem is serious and represents an increasing threat to yields on presently irrigated lands.

Soil nutrient reserves

Nutrient management. Soils of the tropics present special nutrient management problems compared to those in the temperate zone. In addition, particularly in areas cultivated for long periods such as in Asia (India), the land is virtually mined of its nutrients, and no gains in productivity can be achieved in the absence of an integrated nutrient management program. In most cases fertilizer use is a fundamental requirement for enhanced production as there is no soil in the world that can continuously supply the N, P, K, and other nutrient elements needed for continuous plant growth, without replenishment.
In 1984 it was estimated that fertilizer use in 93 developing countries (excluding China) was about 28 million nutrient tons and this was expected to increase to about 56 million nutrient tons by the end of the century. The rate of increase was estimated to be about 4.2%. However, current trends suggest only an increase of 3% with large shortfalls in Africa. This will necessarily impact food production in many countries. In addition Europe and parts of western Asia are also expected to reduce their fertilizer use which will affect the supply of grains through trade and other means. The latter will aggravate the hunger and malnutrition situation in many developing countries. Appropriate programs and policies must be put in place by countries as soon as possible to thwart this potential negative condition.

The previously mentioned fertilizer availability situation coupled with the more important environmental impact of misuse of fertilizers is prompting the conceptual move to a policy of integrated plant nutrient management (IPNM) (Sanchez, 1994). IPNM is a holistic approach utilizing technologies such as crop residue management, biological nitrogen fixation, composting, and crop rotations, in addition to judicious use of mineral fertilizers.

The goal is to determine an adequate input level of each of the components to attain sustainability.

The environmental resource

Conscious assessment of environment and environmental costs is only recently being initiated, even in the developed world. The finite limits of land resources, the extent and rates of land degradation, and the population pressures on the land, all demand a more 'environmental-friendly' land use policy. However, in the developing country context, developing policy initiatives to address these issues is futile until agriculture is productive. In addition, the off-site damages of poor farm land management have additional costs which are not perceived by the farmers and which by comparison to on-farm losses, are much greater in magnitude. These include sedimentation of aquatic resources, siltation of reservoirs, and the multiplying confounding effect on the ecosys as a whole. Finally, the increased use of land for agricu has induced untold damage ... habitat and biodiversity.

A sustainable use of current agricultural land can reduce the environmental off-site pressures. Coupled with other socioeconomic polic decisions, it can also reduce the pressures on marginal land or stressed ecosystems (Virmani, et al., 1994). T : the outcome of appropriate soil, water, and nutrient management policies and a widescale implementation of these policies will not only enhance productivity of land but also protect the environment (Greenland, et al., 1994, Pinstrup-Anderson and Pandya-Lorch (1994)).

Finally, a potential problem area is the impending threats of global climate change. The negative impacts of climate change will be enhanced if soil, water, and nutrient management is not practiced. At the same time, there are some zones in the developing world such as the desert fringe areas and the savannas where the impact of climate change may be more strongly felt. These are also areas of increased land use, population growth and consequent stresses on the ecosystem which may be more adversely impacted.

The socioeconomic resources

Socioeconomic conditions and poor economic returns prevailing in many developing countries are cited as reasons for lack of technology adoption or at least the slow rate of adoption. Any strategy of sustainable land management must not only take these into consideration but be cognizant of the fact that in their presence, failure in technology adoption is almost guaranteed. Over two billion people constitute the rural farming population and agriculture is their main source of income and employment. The two means of reducing rural poverty are intensification of land use on existing agricultural lands and increased rural employment. As prospects for the latter are often not high in developing countries, the emphasis and strategy are towards the former in an environmentally friendly manner.

Very often biophysical and socioeconomic processes are interlinked. Environmental degradation in tropical countries is largely caused by human action driven by poverty, population dynamics, and myopic government economic and land policies. Similarly, socioeconomic factors are often seen as barriers to technological solutions: e.g., delivery system (weak extension), economic system (prices or inappropriate subsidies), political system (wrong policies), or cultural systems (traditional farmers). However, land management is controlled by human decisions and actions and technical solutions are not sufficient. Thus a new paradigm built upon feedback between biophysical/technology development research and socioeconomic reality, with perhaps a greater emphasis or at least more sensitive to the latter, is needed.

With increasing populations, access to land becomes a major factor in realizing the benefits of agricultural development and thus alleviating poverty. In many countries, the trend is to exploit marginal lands. This, together with the increased pressures on good land, enhances the concerns for conservation and sustainability. Maintaining land quality is not only a technological question, it is also a socioeconomic issue which requires awareness and training for society at large. The societal cost of degradation is still being debated, but at some time in the future, suitable policies incorporating these costs must be initiated for any land management technology to have lasting impact.

Table 4, summarizes some of the major problems in soil, water, and nutrient management (see Greenland, et al., 1994). Some new directions are needed to tackle these problems and these deal with four interrelated issues. First, natural resources are no longer per d as merely a medium for plant growth but in terms of local and global functioning ecosystems. All the conventional sciences are poorly uipped to deal with these new 'ecological' and ethical arguments. Second, compared to crop and pest management, natural resource management is highly complicated for both farmers and scientists. This complexity is due to linkages within sociopolitical hierarchies and scales of intervention. Third, there are serious deficiencies of conventional policy tools in effectively and sustainably managing and regulating use of natural resources. National policies, for various reasons, frequently run counter to long-term sustainable development at the local level. Fourth, new analytical concerns such as time, hierarchy/scale, and societal versus individual values require new approaches to solving problems. Finally, there is no universally applicable policy. Each country and region needs policies tailor-made to its endowments or lack thereof.

The information and knowledge base

Information and knowledge play an integral part in the effort to reduce degradation and attain sustainability. The test of utility of sustainable land management technologies is if they are adopted by the farmers. In many countries, the significance of local farmer knowledge is yet to be appreciated. In many instances, reluctance of farmers to accept technologies may be related to conflicts with their abilities in understanding the problem or their perceptions of the problem. Local farmer knowledge must be integrated with scientific knowledge to ensure progress towards sustainability.

A major deterrent to formulation of appropriate land use policies in most developing countries is the absence of resource information. Discriminatory use of the land, targeting research and development activities, and assisting the farmers in the management of land all require information on the soil resources. The absence of base line information has been an important cause of failure of technology transfer, including the transfer of high-yielding germ plasm. The ability to take the minimal information available and make it scale and user relevant are big challenges for decision makers, scientists, and extension workers.

Quality of knowledge (Table 4) is very important, particularly in developing country situations where base line information is scarce. The ability to take the minimal information available and make it scale and user relevant is a big challenge both for scientists and extension workers.

It is well recognized that in the developing societies, the underlying causes of land and water degradation are socioeconomic. However, correcting the socioeconomic conditions is only a partial solution, as it will not restore the productivity of the biophysical resource base. This can only be achieved through improved soil and water management (taking into account the socioeconomic factors) , to ensure that production of food, fue', and fiber can be sustained and the environment protected.

IMPACTS OF LAND DEGRADATION

Land degradation is a major source of environmental instability and unsustainability of agriculture (WRI, 1990 a, b). In the developed countries, capital-intensive labor-substituting technologies have led to substantial gains in productivity (which may or may not be sustainable). Many consider that these productivity gains have been achieved at considerable cost to the environment and natural productivity of the soils. In Canada, Dumanski et al (1986) have reported a significant decrease in soil quality due to land degradation. Although past concerns of soil d dation focused on productivity losses, the off-farm impacts of soil erosion such as the nonpoi.-source pollution of surface water r' ources is potentially a more serious concern (Clark, et al, 1985) in developed countries and becoming better recognized in third worl' c unt.ies. The recent study of Peierls et al, (1991) on human influence of river nitrogen shows that (fig. 2) the volume of nutrients entering coastal waters is correlated with the number of people in the watershed. As some of the larger watersheds are trans-national, land degradation is an international problem.

Land degradation and intensive use of agricultural chemicals is recognized as the major non-point source of water pollution (CAST, 1992). Soil erosion results not only in the movement of sediments but also associated and dissolved phosphate, nitrates, and pesticides from croplands to waterbodies. Eutrophication occurs in surface waters reducing its quality.

The cost of on-site and off-site damage resulting from land degradation is not available for most countries. Informed opinion suspect that the ratio between the two is of the order of 1:10 to 1:100. On-site damages are often related to crop productivity losses and a comprehensive study of this for the United States was made by Crosson and Stout (1983), although they acknowledge the lack of data and knowledge about relationships between soil characteristics, productivity, and erosion. In their review, however, they note that crop productivity losses are in general small (2 to 8%) and also that these yield declines are generally not sufficient to judge the importance of the losses to society. This is one of the reasons for the lack of attention to such measurements. Impacts on productivity, however, are only part of the question. In Ethiopia, a detailed assessment by Hurni (1993) indicates that soil erosion (estimated to be 1.5 billion tons annually from the highlands) results in about 1 to 2% loss in productivity which translates to about 15 million dollars annually. The nutrients that are lost annua y however, re estimated to cost bout one billi dollars f the soil is to be replenished. If the situation becomes extreme, as in Haiti, parts of central Africa and other countries where steep lands are extensively used, erosion will reduce the soil depth to less than 10 cm and land will be abandoned and beyond rehabilitation.

There are generally better estimates of off-site damages than for losses in productivity and Clark, et al, (1985) in an initial estimate for the United States, cite off-site impacts such as in-stream damages caused by sediments, nutrients, and other erosion-related contaminants of water-bodies, and 'off-stream' damages which occur before the sediment or contaminants reach the main water-bodies. In the U.S., soil erosion from a ricultural lands is identified as the major cause of non-point water pollution. Table 5 provides an estimate of water-caused erosion on nonfederal lands for the year 1977 and estimates of cost of the off-site damage due to soil erosion (Clark, et al, 1985) are reproduced in table 6. Though these estimates are more indicative than definitive, as the source of the damage is usually multiple and clear linkages to factors usually cannot be established, the total damage is of the order of 3 to 13 billion dollars. No estimates for biological impacts are made due to inherent difficulties. Another more recent, unpublished, estimate for off-site damage in the U.S. resulting largely from erosion is estimated to be about 450 billion dollars. Few countries can accept such costs; in some instances the costs may be higher than the GNP of the country. In Canada, the loss in productivity due to erosion and other forms of land degradation is about 2 billion dollars, which is about 12 per cent of agricultural GNP. These estimates suggest that environmental degradation results in a net reduction of about 15 per cent of agricultural GNP globally. In the U.S., Ribaudo (1989), estimates that the Conservation Reserve Program designed to remove 40 to 50 million acres of highly erodible cropland from production may generate an estimated 3.5 to 4 billion dollars in water-quality benefits alone. These benefits stem from lower water treatment costs, lower sediment removal costs, less flood damage, and increased recreational fishing. The importance of land degradation and the need for mitigating management will only result if such monetary environmental accounting is in place in all countries.

Another major concern is the less obvious impact of land degradation arising from the conversion of natural habitats to agricultural and other uses. This is now recognized as a major contributor to loss of genetic stock and diversity. At current levels of conversion (with accompanying accentuated negative changes resulting from degradation), it is estimated that 25 percent of the world's plant species will disappear in the next 50 years (IDRC, 1992) and these are permanent losses as ecosystems seldom revert to their original composition.

The three principal features of resource poor farmers of the developing world are diversity, subsistence, and common resource ownership (or lack of thereof) . The farmers perception varies of what is or what is not a productive resource, and as a result their use of the resource varies. To some extent the farmer's perception is locale specific, thus his/her information base for making judgements and actions is determined by the conditions in the vicinity of the farm. Larger tracts of land such as watersheds and down-slope areas, including coastal dwellers, who are impacted by actions on the hinterland, are beyond the view of the upland farmer. Adding this space and time dimension to the degradation problem makes it not only a resource research and management issue, but also a human and social issue. Solutions to these obstacles are not easily available. It is evident that countries should adopt policies that support mutual goals of optimum soil quality, clean water and sustainable farming.

CONCLUSION

Policies and issues in the interface between agriculture, forestry and the environment remain a major obstacle in the implementation of sustainable land management. Historically agriculture, forestry, and environment have been considered as sectors, and past approaches were to develop sector-based policies. There is an increasing recognition for an ecosystem approach to land management and many have recommended a unit of the land-mass such as the watershed or ecoregion for policy and management. Such a biophysical unit permits assessment and monitoring of not only components but also interactions between components.

There are few assessments on the impact of agricultural policies on environment and forestry, specifically within a watershed or catchment. The effects on the environment and on forestry from agricultural policies depend on the environmental signals that policies transmit and the levels of farm support provided. Agricultural policy reform could emerge as the main driving force towards a closer integration of agriculture, forestry, and environment. Accomplishing this is not an easy task as each stake-holder will attempt to enhance their productivity with often no knowledge or regard for adjoining entities. To assure the sustainability of the system as a whole, the following actions are proposed for considerations:

* create awareness for the need to manage the system as a whole and establish the interrelationships that sustain environmental support systems;

* adopt an ecosystem based approach for policy and management decisions for sustained land use, recognizing that ecosystem based decisions may conflict with political desires;

* understand the time and space impacts of planned actions, specifically considering resilience, diversity, cycling, and interdependence;

* evaluate productivity or economic risks and uncertainty in the context of ecosystem risks to arrive at optimum land uses.

The rewards of minimizing land degradation are many and the most obvious are:

* stronger national economies through the implementation of cost-effective and sustainable land management practices that are also conducive to a cleaner and safer environment.

* improved national security, particularly food security, that results from a responsible agricultural strategy that minimizes resource depletion thereby reducing social conflict and accompanying ecological damage.

* enhanced long-term assurance of biodiversity resulting from a balanced land-use policy.

In the final analysis, the test of sustainability in developing countries is the behavior of the limited resource farmers. Sustainable agriculture development will be elusive in these countries if these farmers are not convinced of the short- and long-term benefits, particularly, the economic benefits. Sustainability and land use solutions to global environmental problems only result if the millions of individual farmers operate in an appropriate policy and economic milieu and are backstopped by appropriate technological support services.

An understanding of land resources systems, including the functioning and interactions of each of the components, is *conditio sine qua non* to sustainable land management and to reducing land degradation. The key to intergenerational equity, enhancing economic growth, and assuring sustainability depends on the following premises:

* much knowledge is already available on processes of conversion, distribution, filtration, assimilation, and storage of water and nutrients in the ecosystem. This knowledge must be mobilized in such a way to ensure that transformations and cycling are within the limits of nature, and that the capacity of the land to function as an environmental filter is not exceeded;

* when parts of a landscape are manipulated for human needs, it impacts the whole ecosystem and thus the processes and functions of each part and linkages of each process to the whole need to be understood prior to exploitation;

* the symbiotic and synergistic relationships and interdependencies of landscape components and each of the

functions (such as nutrient cycling, energy generation, shelter, water management, food production, and waste recycling) must be considered for sustained use of the landscape;

* utilization of any of the functions is a form of exploitation, resulting in degradation of the resource base, and that sustainability calls for seeking optimal levels for each of the multiple functions.

A better understanding of degradation processes and the resilience characteristics of the resource base coupled to improved soil, water and nutrient management (Greenland, et al., 1994) is necessary to meet the global challenges of sustained crop production in harmony with good environmental management. This is the challenge and the new agenda for research and development in the immediate future. The ecosystem approach is the key to reducing degradation and instilling sustainability in all land systems. However, as stressed by Pinstrup-Anderson and Pandya-Lorch (1994) the most serious environmental threat in low-income countries is poverty, and a prerequisite to addressing land degradation is addressing poverty.

REFERENCES

Buringh, P. 1989. Availability of agricultural land for crop and livestock production. In: D. Pimental and C.W. Hall (Eds.) Food and Natural Resources (pp 69-83). San Diego. Academic Press.

CAST (Council for Agricultural Science and Technology), 1992. Water Quality, Agriculture's role. CAST, Ames, Iowa. 103 pp.

Clarke, E.H., J.A. Haverkamp, and W. Chapman. 1985. Eroding soils: The off-farm impacts. The conservation Foundation, Washington, D.C.

Crosson, P.R. and A.T. Stout. 1983. Productivity effects of cropland erosion in the United States. Publ. Resources for the Future, Washington, D.C. 103 pp.

Dent, F. J. 1990. Land resources of Asia and Pacific. In: Report of expert consultation of the Asian network on problem soils. FAO, Bangkok. 44-49.

Dudal, R., G. Higgins, and A. Kassam. 1982. Land resources for the world's food production. Proc. 12th. Int. Congress Soil Science, New Delhi.

Dumanski, J. 1994. Strategies and opportunities for soil survey information and research. In: Zinck, J.A (Ed.) . 1994. Soil Survey: Perspectives and strategies for the 21st. Century. Publ. International Institute for Aerospace Survey And Earth Sciences. Encheue, The Netherlands. 36-41.

Dumanski, J., D.R. Coote, C. Luciek, and C. Lok. 1986. Soil Conservation in Canada. J. Soil and Water Conservation Society. 41:204-210.

24

Dumanski, J., E. Pushparajah, M. Latham, and R.J.K. Myers. 1993. Evaluation for Sustainable Land Management in the Developing World. vols.1-3., IBSRAM proceedings, No.12. IBSRAM, Bangkok, Thailand.

Dumanski, J. and A.J. Smyth. 1994. The issues and challenges of sustainable land management. In: R.C. Wood and J. Dumanski. Sustainable Land Management for the 21st Century. Vol. 2: 1122. Publ. Agric. Institute of Canada, Ottawa.

Eswaran, H. 1992. Role of soil information in meeting the challenges of sustainable land management (18th Dr.R.V. Tamhane memorial lecture). J. Indian Soc. Soil Sci. 40:6-24.

Eswaran, H. 1993. Soil resilience and sustainable land management. Ed. D.J., Greenland and I. Szabolcs. Proceedings of international symposium on soil resilience and sustainable land use. Wallingford, UK. Cambridge University Press. 21-32.

FAO 1976. A framework for land evaluation. FAO Soils Bulletin No. 32. Rome, Italy: FAO. 72 pp.

FAO 1989. Sustainable agricultural production: implications for international agricultural research (compiled by the Technical Advisory Committee of the CGIAR). FAO Research and Technical Papers no. 4. Rome, Italy: FAO. 131 pp.

FAO. 1993. Agriculture towards the year 2010. FAO, Rome

Greenland, D.J., G. Bowen, H. Eswaran, R. Rhoades, and C. Valentine 1994. Soil, water, and nutrient management research: A new agenda. Publ. IBSRAM, Bangkok, Thailand. 72 pp.

Hudgens, R. E. 1992. Selecting technologies for sustainable agriculture. Publ. Winrock International, Institute for International Development., Morrilton, Arkansas. 39 pp.

Hurni, H. 1993. Land degradation, famine, and land resource scenarios in Ethiopia. In: D. Pimental (ED.) World Soil Erosion and Conservation. Cambridge Studies in Applied Ecology and Resource Management, 27-61.

IDRC (International Development Research Center). 1992. Our Common Bowl. Global Food Interdependence. IDRC, Ottawa, Canada, 64 pp.

Oldeman, L.R., Hakkeling, R.T.A., and Sombroek, W.G. 1990. World map of the status of human-induced soil degradation: an explanatory note. Wageningen, Netherlands: International Soil Reference Center. 34 pp.

Pimental, D., R. Harman, M. Pacnza, J. Pecarsky, and M. Pimental. 1994. Natural resources and an optimum human population. Population and Environment. 15: 347-368.

Pinstrup-Anderson, P, and R. Pandya-Lorch. 1994. Alleviating Poverty, Intensifying Agriculture, and Effectively Managing Natural Resources. Food, Agric., and the Environment Discussion Paper 1. IFPRI, Washington D.C.21 pp.

Peierls, B., N. Caraco, M. Pace, and J. Cole. 1991. Nature, 350:386-387.

Ribaudo, M.O. 1989. Water quality from the conservation reserve program. Economic Research Service, USDA. Agric. Economic Report No. 606. 30 pp.

29

Ruttan, V.W. 1987. Institutional requirements for sustained agricultural development. In: sustainability issues in agricultural development, ed. T.I. Davis and I.A. Schrimer. Washington D.C. World Bank.

Sanchez, P.A. 1994. Tropical soil fertility research: Towards the second Paradigm. Proc. 15th Intl. Congr. soil science, Acapulco, Mexico. 1: 65-88.

Virmani, S.M., J.C. Katyal, H. Eswaran, and Abrol, I. (Eds.) 1994. Stressed Agroecosystems and Sustainable Agriculture. Publ. New Delhi, India.

WCED (World Commission on Environment and Development). 1987. Our Common Future. Oxford, Oxford University Press.

World Bank. 1990. Irrigation and drainage research: A proposal. Agricultural and Rural Development Department, World Bank, Washington, D.C.

World Resources Institute. 1990a. Land Cover and Settlements. p 267 -7. . In: Hammond A.L. et al. (ed.) World Resources 199091. A report by the World Resources Institute, Oxford University Press, Oxford, England.

World Resources Institute. 1990b. Food and Agriculture. p 277-290. In: Hammond A.L. et al. (ed.) World Resources 1990-91. A report by the World Resources Institute, Oxford University Press, Oxford, England.

Table 1. Continental and global extent of chemical soil degradation (Million Ha)

	Loss of Nutrients	Salini-zation	Pollution	Acidification	Total	%
Africa	45	15	+	1	62	12
Asia	15	53	2	4	74	10
S. America	68	2	-	-	70	29
C. America	4	2	-	-	7	2
N. America	-	+	+	+	+	+
Europe	3	4	19	+	26	12
Oceania	+	1	-	-	1	1
World	136	77	21	6	240	12

Table 2. Continental and global extent of physical soil degradation (Million Ha)

	Compaction Crusting	Water logging	Subsidence Organic soils	Total	%
Africa	18	1	-	19	4
Asia	10	+	2	12	2
S. America	4	4	-	8	3
C. America	+	5	-	5	8
N. America	1	-	-	1	1
Europe	33	1	2	36	17
Oceania	2	-	-	2	2
World	68	11	4	83	4

Table 3. Causative factors of human-induced soil degradation (Million Ha)

	Deforestation	Over-Exploitation	Overgrazing	Agric. Activities
Africa	67	63	243	121
Asia	298	46	197	204
S. America	100	12	68	64
C. America	14	11	9	28
N. America	4	-	29	63
Europe	84	1	50	64
Oceania	12	-	83	8
World	579	133	679	552

Table 4. Soil, water and nutrient management problem areas

RESOURCE	COMPONENT	PROBLEM
SOIL		
	- Land quality	
		* Soil degradation
		* Water erosion
		* Wind erosion
		* Waterlogging/salinization
		* Chemical degradation
		* Physical degradation
		* Biological degradation
		* Nutrient base
	- Land quantity	
		* Non-agricultural use of land
		* Fragile ecosystems
		* Resource information
	- Nutrient availability	
		* Reduced soil fertility
		* Loss of biological activity
WATER		
	- Water quality	
		* Pesticide contamination
		* Nutrient excess contamination
		* Salinity/alkalinity
		* Sedimentation
	- Water quantity	
		* Water use efficiency
		* Non-agricultural demand
		* Flood management
		* Waterlogging
SOCIOECONOMIC		
	- Socioeconomic quality	
		* Sociological factors in technology adoption
		* Socially disadvantaged farmers
		* Rural sector policies
		* Societal role in conservation
		* Societal role in sustainability
ENVIRONMENT		
	- Environment quality	
		* Vegetation degradation
		* Climate degradation
		* Interacting stresses
		* Habitat destruction
INFORMATION		
	- Information quality	
		* Scale relevant information
		* User relevant information
		* Indigenous knowledge
	- Information quantity	
		* Availability of base line data
		* Processing/packaging of information

Source of Erosion	Amount (million tons/year)	Percentage of US non-federal Land
Cropland	1,926	38.3
Pastureland	346	7.0
Rangeland	1,155	23.3
Forestland	435	8.8
Streams	553	11.1
Gullies	298	6.0
Roads	169	3.4
Construction sites	80	1.6

Table 5. Water-caused erosion on nonfederal land in the US, 1977

(Source: USDA Soil Conservation Service (1981). 1980 Appraisal Part I. Soil, water, and related resources in the United States: Status, conditions, and trends. US Govt. Print. Office, Washington DC, 98 pp)

30

Type of impact	Range of estimates (million US $)
In-stream effects	
Biological impacts	
Recreational	950 - 5,600
Water storage	310 - 1,600
Navigation	420 - 800
Other in-stream uses	460 - 2,500
Off-stream effects	
Flood damage	440 - 1,300
Water conveyance facilities	140 - 300
Water treatment facilities	50 - 500
Other off-stream uses	400 - 920

Tablle 6. Estimates of off-site costs in 1977, in the U.S. (After Clarke et al, 1985).

31