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J. Keith Syers, John Lingard, Christian Pieri, Exequiel Ezcurra and Guy Faure

Sustainable Land Management for the Semiarid and Sub-humid Tropics

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Sustainable land management (SLM) ensures adequate levels of current production whilst preserving the land resource base over time in order not to compromise or reduce development opportunities for future generations. This is particularly important globally in the large areas of the semiarid and sub-humid tropics. This paper presents five case studies involving different land management systems in Africa, Latin America, and Asia. Biophysical and socioeconomic causes of land degradation are first outlined, the linkages between them discussed, and regional commonalities and differences outlined. Practical procedures and recommendations are made on how to reverse the spiral of land degradation. These include the need to assess land degradation and sustainability, land quality change indicators, linking biophysical and socioeconomic information, and the institutional and funding mechanisms which may be necessary. A multidiscilinary and participatory approach directly involving the land users themselves is also recommended.

INTRODUCTION

Sustainable land management (SLM) ensures adequate levels of current production whilst peserving the land resource base over time in order not to compromise or reduce development opportunities for future generations. This is particularly important globally in the large areas of the semiarid and sub-humid tropics. This paper presents five case studies involving different land management systems in Africa, Latin America, and Asia. Biophysical and socioeconomic causes of land degradation are first outlined, the linkages between them discussed, and regional commonalities and differences outlined. Practical procedures and recommendations are made on how to reverse the spiral of land degradation. These include the need to assess land degradation and sustainability, land quality change indicators, linking biophysical and socioeconomic information, and the institutional and funding mechanisms which may be necessary. A multidiscilinary and parcipatory approach directly involving the land users themselves is also recommended.

Sustainable land management is important for two interdependent reasons:

(i) Land provides the base of production, in terms of food, fiber, wood, and other natural products, required by the evolving needs of populations and ensuring sustainable development without compromising the future; and

(ii) SLM is fundamental to minimizing hazards and ensuring a hospitable environment for humans and other living organisms, by combating land degradation.

SLM must be considered over scales of time and space. Medium- (one generation) and long-term intervals of time can be identified. But in fragile environments, short-term mismanagement can induce a dramatic deterioration in the potential productivity of soils, with a resulting decrease in the efficiency of inputs applied to make the land more productive. As a consequence, there will be a decrease in the flexibility of farming practices, a limit on innovative cropping and farming systems, and an increase in the costs of production. Also, in terms of space, nutrient transfers from one area to benefit cropland elsewhere can result in land deterioration. Disequilibrium in the proportion of land dedicated to fuelwood production (often to the benefit of cities, not rural areas), cattle raising, and crop production can create major long-term problems for rural populations through income transfer and the deterioration of land and water resources.

The semiarid and sub-humid tropics require particular attention because of their areal importance on a global scale (Fig. 1), their higher potential for production because of the better availability of water than in more arid areas and the higher reserves of nutrients than in more humid areas; a lower incidence of health and disease problems than in more humid areas; and the higher population density, which acts as a stimulus to market formation and development. However, the development of these ecosystems has been restricted to a few products, particularly to the transformation of natural vegetation to cattle grazing land, which often drastically reduces vegetation cover leading to soil erosion. The decline in food production associated with the degradation of grazing lands is one of the most obvious impacts of desertification.

There is an urgent need to define and develop new and sustainable systems of land management in semiarid and sub-humid regions to enhance productivity and conserve the stock of plant and animal biodiversity, and to minimize the negative impacts of more arid and more humid regions, for which the semiarid and sub-humid tropics act as a major buffer.

This paper is concerned with a global perspective of SLM in the semiarid and sub-humid tropics, drawing on case studies from Africa, Latin America, and Asia (19) and outlines requirements and recommendations for reversing the spiral of land degradation.

CAUSES OF LAND DEGRADATION

Land degradation has been occurring widely in the semiarid and sub-humid tropics for the past few decades and its causes are reasonably well understood (2). Whilst recognizing that there are close linkages between the biophysical, social, and economic causes of land degradation, it is convenient to consider them separately, at least for simplicity of discussion.

Biophysical

The UNEP project on "Global Assessment of Soil Degradation" (GLASOD) was an important step forward in providing a regional and global quantification of the extent and seriousness of soil degradation processes (3).

Degradation processes operate to a varying extent in the semiarid and sub-humid tropics but in these warm, seasonally dry regions, some processes are more important. Because of warm temperatures at those times of the year when moisture is not limiting, the kinetics of chemical reactions are enhanced, with the consequence that the depletion of organic matter and nutrients is the most important cause of land degradation (2, 4).

In such situations, the use of green manures and crop residues are unlikely to make a major contribution to building stable organic-matter levels in soils. Loss of organic matter causes a deterioration in physical properties, which can lead to increased soil erosion because of compaction, crusting, and sealing at the soil surface, which results in enhanced surface runoff. Nutrient depletion is a particularly important cause of soil degradation, as shown by several nutrient balance studies (5).

On sloping land, soil erosion processes contribute to the loss of organic matter and nutrients as topsoil is removed. Thus, although erosion is a major cause of unsustainability, it is usually a secondary cause, the primary cause being inappropriate land management practices. Farmer reluctance to accept soil conservation measures to reduce soil erosion, because ot the lack of a strong relationship between soil loss and crop yield decline, in the short term, does not augur well for reducing land degradation on sloping land.

In addition, salinization and waterlogging are important contributions to soil degradation in several developing countries.

Social and Economic Dimensions

Land degradation is brought about by human behavior, directly by land users and indirectly by policy makers and traders in domestic and international markets. Changing land use is induced by economic forces and demographic pressures, and artificially induced, nonsustainable systems may result. Only by analyzing the reasons underlying these forces, can we begin to understand the complex biophysical, social, and economic relationships which cause land degradation.

Macroeconomic policies in terms of foreign exchange rates, international trade regimes, monetary and interest rate policies, food and fiber output pricing, input prices, and the taxation or subsidization of agriculture provide the economic setting for land-using activities. Onto these are grafted specific sectoral policies for agriculture and forestry in terms of marketing, credit, extension, water and energy pricing, and mechanization. A third layer of policy comes via property rights, land-tenure arrangements, and access to resources. These shape human behavior, along with the underlying biophysical relationships, technology, and institutions, resulting in an array of household incomes, employment, income distribution, poverty, gender dimensions and social participation.

The question arises as to why nonsustainable practices occur. Why do land users not adopt conservation measures and which social and economic dimensions are the major constraints to SLM? How can we provide an economically and environmentally attractive way to foster sustainable growth in crop, wood, and animal production?

Effective natural resource management research and policies must provide economic opportunities to farmers for input substitution, enterprise substitution, and trade-offs among sub-systems. Crosson (6) highlights the role of knowledge and information on environmental and economic impacts of technical alternatives. A major threat to resource degradation is the potential lack of knowledge, particularly the highly valuable and vanishing resource of existing indigenous knowledge. The possible loss of the capacity to produce new knowledge to be embodied in people, technology, and institutions, will impair our ability to devise appropriate survival strategies.

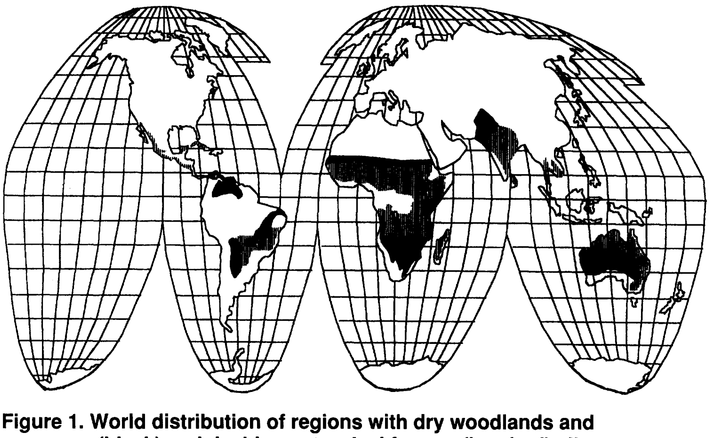


Figure 1. World distribution of regions with dry woodlands and savannas (black) and deciduous tropical forests (hatched) climax vegetation types, modified from Walter (1). These regions are defined basically on climate attributes and coincide, respectively, with semiarid and with sub-humid tropical environments.

Widespread adoption and sustainable techniques will depend on the overall market policy, regulatory, and institutional environment. This suggests that cost-benefit analyses of proposed new techniques should be carried out at the farm, national, and global level.

Land-use management techniques will be required to pass cost-benefit tests at all three levels before they are adopted in a globally sustainable manner. Changes in economic theory are underway to ensure more complete accounting for use and misuse of natural resources and to put a higher value on environmental maintenance (7). However, because many of the benefits will not accrue directly to the land user, there still remains the question of who will finance the package. Equity issues and financing questions at the national and global levels must be addressed.

Linkages

Biophysical land degradation has its roots in household and social behavior. The resource structures of farm households (land, labor, capital, and managerial ability) combine with production objectives and decision-making to produce specific crop and animal enterprises and associated soil management strategies. Underlying these are the economic pressures on the household to survive and defend its livelihood in the short term and long term, but importantly, in that order. Often individual farmers and societal interests diverge due to short-termism. There are few immediate rewards to farmers for enhancing soil resilience, ecological sustainability, and biodiversity.

Put simply, there are no market prices for resilience, sustainability, and diversity. Thus, farmers ignore them because they do not appear in private profit and loss accounts. Short-term, private profit and household income matter more to farmers with a short planning horizon; many benefits of soil management practices are off-farm/off-site (e.g., reduced downstream water pollution) and society has a longer-term planning horizon. The off-site social costs of erosion/degradation are ignored and, if decision-makers are to take them into account, market prices must be manipulated to provide incentives for farmers to adopt socially optimal soil management practices. Alternatively, support by government of local communities to manage soil resources in a community-social-base fashion has its advocates (8).

This explains why, despite the efforts of research and extension services, technologies which appear sound, fail to be adopted on a scale to effect change. For example:

(i) Fertilizer use in Sub-Saharan Africa, which is currently less than 10 kg arable ha^{-1} yr^{-1}, persists at low levels whilst nutrient mining of soils continues under cropping systems; a major cause is that the cost of fertilizers at the farm gate is too high.
(ii) Soil erosion control techniques by mechanical means (e.g., terracing) are seldom accepted if they are not subsidized and are rarely maintained. Possible explanations are local labor shortages and farmers' discount rates as high as 80%.
(iii) Nonpricing of irrigation water results in overuse by those with easy access and environmental damage and water stress for downstream users. Schemes for water pricing are considered regressive and unfair to low income farmers, but tradeable water permits issued to farmers allow them to efficiently allocate water; shareholders often sell their shares, thus allocating scarce water efficiently and addressing equity concerns.
(iv) Most countries have a system of private or state ownership of forests, disregarding customary, community-based use rights. Property rights to a forest fail to internalize the environment benefits of forest conservation, because the private discount rate exceeds the social discount rate. Experience in Papua New Guinea has shown that communal tenure prevents deforestation more effectively than private or state ownership.

The discounted benefits farmers and society receive from adopting soil management practices are cumulative over time and may not match costs during the initial years following adoption, particularly at high interest rates. Logically, such private land users choose not to adopt soil management practices. Likewise, policies which do not price scarce natural resources result in nonoptimal practices. Failure to control access to natural resources by defining and enforcing clear property rights will result in overgrazing, fertility depletion, and degradation. Government policies often artificially bias land use towards cash crops, compared to indigenous food crops for subsistence.

The links between biophysical land degradation and socio-economics are clear. Land degradation is a special case of market failure in natural resource and agricultural markets. What is required is a recognition that scarce resources must be priced, property rights must be enforced, and institutional arrangements put in place to implement and monitor SLM.

REGIONAL COMMONALITIES AND DIFFERENCES

Ecological Distribution

Semiarid and sub-humid ecosystems are the most common in Africa and Latin America. They range from Mediterranean-type ecosystems (maquis in northern Africa, fynbos in southern Africa, the Chilean matorral in South America, and the Mexican chaparral), to tropical dry forests and savannas (the Sahelian and Sudanian savannas and the Kalahari semiarid scrub in Africa, the Cerrado in Brazil, the Chaco, the Llanos of Venezuela, and the Pacific dry forests of Central America and Mexico), and include high-altitude dry habitats, like the Andean Puna.

In both African and American continents, dryland ecosystems occupy more than 50% of the land area. Significant differences exist between both continents. In Africa, the semiarid ecosystems form part of large ecotones between the wet tropics and the Sahara and Kalahari deserts. African drylands are subject to large-scale environmental changes in these deserts. That is, the environmental dynamics of the large African deserts modulate large-scale environmental processes in the semiarid zone. In Latin America, most of the large tropical and sub-tropical drylands are not part of transitional ecotones towards deserts, but exist as a result of the general atmospheric circulation and the distribution of climatic zones.

African and Asian semiarid areas contain sandy soils which are nutrient-poor and vulnerable to water and wind erosion. In Latin America sandy soils are rarer, and water erosion is the most common cause of soil loss. Nutrient deficiencies resulting from the nature of highly-weathered tropical soils are common in African and Asian sub-humid habits and in some of the Latin American drylands, like the Cerrado and the Sertao. In all these areas, P deficiency, low organic matter content, and soil acidity are limiting factors. In other Latin American drylands, soils are genetically younger, or derived from limestone, and these problems are not so severe. This is the case in the Pacific dry forests in Mexico, and in the Chaco dry forest in South America. In these systems, water availability seems a more limiting factor.

Land Management and Population Pressures

Population growth is a major force in land degradation in semiarid and sub-humid ecosystems (9). Some of the areas with highest population densities lie in these environments. Some of the large megalopolises, like Bangkok, Lima, Mexico City, Nairobi, and Santiago, lie in semiarid or sub-humid areas.

Growing population pressure, has strongly influenced the farming systems and land management in Africa, Asia, and Latin America. Because of the ever increasing pressure on available land, shifting cultivation is disappearing, cultivation periods become longer while fallow periods are reduced in time. As a consequence, agricultural inputs increase while yields of the traditional systems decrease. In such agriculture, labor productivity remains high, unless yields decline.

The changes related to land management can be more signifi-

Box 1:
Slash and burn systems in Latin America

The most common cause of deforestation in semiarid and sub-humid, tropical ecosystems is clearing for agriculture, but cattle husbandry is a less direct, but profound cause of forest disappearance (10). Small tenants (*campesinos*) clear dry forests to develop small areas for agriculture, but after a few years the fertility of the soil declines and they are forced to sell or abandon their plot, which is then appropriated by ranchers. The latter recover impoverished areas for extensive grazing by implanting African grasses, which are very productive in the pest-free environments of Latin America and frequently become invasive. Thus, a growing cycle of land degradation is created, where prime forest is cut, developed for agriculture, and managed by *campesinos;* later abandoned and converted into monospecific pasture fields managed by extensive ranchers, while the *campesinos* move on to clear new forests. The result is the conversion of species-rich forest with fertile soil into a monospecific pasture of low, but relatively sustained production.

Where land pressure becomes a more important constraint, new cropping systems are identified. These systems can include new crops or better rotations. Farmers use more fertilizers or develop agroforestry techniques or mixed farming systems.

Box 2:
New cropping systems in southern Togo

In southern Togo, the climate is characterized by annual rainfall of between 800 and 1200 mm in two seasons which are not well defined. Climate risk remains high and a drought period can occur. The dry period is relatively short. This climate is not favorable for cattle because of trypanosomose disease. Before population settlement, the region was covered by dry forest and savannah but farmers have now destroyed almost all the natural forests.

At first, the common cropping system involved shifting cultivation. After clearing the natural vegetation, farmers cultivated yam. After harvesting they remained for 2 or 3 years on the same plot growing maize, peanuts, and cassava. But when the land pressure became greater and the fallow period too short for restoring the soil's fertility, the farmers changed their cropping system. Now the main crops are maize, grown during the first rainy season and cotton, which is sown just before harvesting maize. Cotton represents between 40 and 50% of the cultivated land and is always fertilized. The following year maize is able to use the added nutrients partially available in the soil. Before weeding or nutrient depletion becomes a major problem, farmers plant young palm trees. When the trees mature they stop cultivating annual crops. After 10 or 20 years they cut the palm trees which provide alcohol sold on the local market. On such a field which has been regenerated by a type of cultivated fallow they start a new cycle. Without fertilizer the average maize yield is 1000 kg ha^{-1} and the cotton yield reaches 800 kg ha^{-1}. These are not high, but by following this cropping system farmers are able to maintain the yield level for many decades.

However, this model is no longer valid. The population density is now about 30–40 inhabitants per km^2 and young men and women have trouble finding new land. In future, palm tree fallow could be less popular and nutrient depletion could become a major problem related to the control of soil acidity.

Box 3:
Upland rice in northern Thailand and Laos

Rice is the basic subsistence crop grown under shifting cultivation in the uplands of northern Thailand and Lao PDR. It is grown by the majority of farmers, with yields ranging from approximately 600 to 2400 kg ha^{-1}. Yields have increased little in recent years. The shortening of the rotation (38, 20, and 5 yrs for the 1950s, 1970s and 1992, respectively, in Lao PDR), because of increasing population pressure, reduces the area available for slash and burn agriculture, and yields are likely to decrease because of increased weed problems and soil fertility decline. A further problem results from the cultivation of opium by hilltribe people. Income generated from opium is used to buy rice so that a reduction in poppy production increases the need for more land for upland rice. If rice yields were improved, opium production could be reduced.

Moving from traditional, long-rotation systems to a more intensive system of shorter rotation presents major weed and soil fertility problems. Studies by the Lao-IRRI Upland Program have indicated that of the 294 days ha^{-1} average labor inputs, some 43% or 126 days ha^{-1} are spent on weeding. The major fallow weed in Lao PDR is *Chromolaena odorata*. In northern Thailand, high weed pressure forces farmers to abandon a newly-cultivated plot after two years; there *Imperata cylindrica* invades aggressively.

Although upland rice is largely grown in monoculture in northern Thailand, mixed cropping with pigeon pea (*Cajanus cajan*) is practiced, the pods being used for human consumption and for animal feed. There are also spin-offs to soil fertility with regard to organic matter and nitrogen inputs. A major challenge facing researchers is to develop strategies which assist farmers in adapting to shorter fallow and longer cropping cycles, particularly with regard to weed control. In Lao PDR, planting teak, intercropped with upland rice initially, is providing a viable alternative to slash and burn agriculture. The main motivations are increased cash income and securing tenure of the land.


An overgrazed plateau in Oaxaca, Mexico. The original semiarid scrub has almost disappeared. Photo: E. Peters.

cant especially when population density becomes higher. Some studies (as in Kenya) indicate that with more people there is less erosion, however, the relationships between population density and SLM are complex. Population growth may induce a change in agricultural technology or cause resource transfer from outside the area. Thus, it is wrong to say that population growth is not compatible with sustainable agriculture, especially in relatively underpopulated countries.

The relationships between farmers and agribusiness also play a key role in the capacity to develop better management systems. In Latin America, there are many farmer organizations which try to obtain better prices for the inputs they buy or the products they sell. This organization is necessary to negotiate with well-structured private or governmental agencies. These organizations are also able to deal with land management and sustainable agriculture based on participatory approaches. In this context, relevant "bottom-up" land management approaches can be observed, like the Cerrados in Brazil for fighting erosion or in Mexico for managing irrigation.

Land Tenure and Land Management

Tenure is a fundamental aspect of land use, directly influencing the access to natural resources. It is a common view that open-

Box 4: Pastoral systems in Sahelian countries

Pastoral areas in Sahelian countries are characterized by annual rainfall between 400 and 800 mm, and a large number of perennial or annual grass species. In terms of land use, these areas are occupied by pastoralists who raise cattle, sheep, and goats. A large proportion of herders used to move during the dry season from the north to the south. Land resources were used collectively and the populations developed well-adapted rules for managing them.

In the last three decades the climate has become more severe with a decrease in annual rainfall. At the same time human population increased rapidly; the annual demographic growth rate is between 2.5 and 3.0%. The cattle population had an erratic evolution during the severe drought period in the mid- 1970s when many animals died. But now, the carrying capacity remains high (0.5 animal ha^{-1}). In the most favorable areas the farmers from the southern regions extended the cultivated areas, cut the trees, and eliminated the more productive rangelands. As cultivation becomes a more significant land use system, pastoralists are denied access to pasture or crop residues, especially during the dry seasons which are of critical importance. The relationship between pastoralists and farmers becomes difficult and generates conflicts.

This trend has severe consequences in concentrating cattle around less productive, fragile areas and waterpoints, and land degradation is accelerated. Overgrazing eliminates some grass species and generates erosion. The scarcity of the vegetative cover can cause major floods during the rainy season. Along with climate change, this is the main explanation for desert extension. In the most populated areas, pastoralists emigrate to the south or transform herding to a mixed farming system. The pastoralism system then becomes marginal.

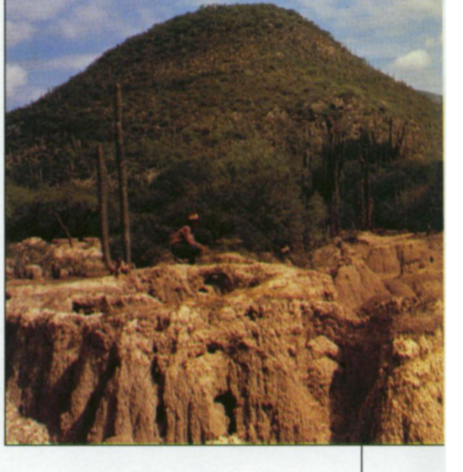
Livestock farming is an appropriate way to develop the Sahel, but land degradation remains a critical problem when carrying capacity is too high. Photo: G. Faure.

Even in the dry Sahelian regions farmers extend the cultivated land and eliminate the more productive rangelands. This can lead to conflicts between farmers and herders. Photo: G. Faure.

Box 5: Irrigated and market-oriented systems in Latin America

In the dry irrigated valleys of Latin America, agro-industrial crops constitute the spearhead of modern irrigated and high-input agriculture. A decrease in international cereal prices, due to the high level of subsidy in developed countries has caused the substitution of wheat and maize by export vegetables and fruits, forage crops, and industrial crops. This has resulted in the inability of many Latin American countries to meet their internal demand for basic food grains, while the production of beef, export crops, and agro-industrial supplies has grown steadily. Thus, Mexico, Peru, and Chile, which depend on their irrigated valleys, have been increasing their agricultural exports (temperate fruits in Chile; strawberries, tomatoes, and vegetables in Mexico), but at the same time have difficulty feeding their populations with basic grains.

Agriculture under irrigation occupies a small proportion of the dryland areas, but contributes the main part of value of the agricultural production. In Mexico, irrigated areas occupy approximately 50% of the national drylands and produce 60% of the agricultural production (11). Farmers in irrigated, intensive agricultural areas are among the most technically developed in Latin America. However, if efficiency is calculated in terms of natural resource use, modern intensive dryland agriculture is wasteful. For example, beef production from underground water-irrigated lucerne demands around 30 000 L water per kg of beef produced, and around 50 calories of fossil fuels per calorie of meat (12). One of the main challenges of current intensive agriculture in semiarid and sub-humid agro-ecosystems is to maintain current levels of production while improving the efficiency of water use and decreasing the impact of agro-chemicals on the environment.



Gully erosion in the Mixtec region of Mexico produced by overgrazing and the loss of plant cover. Photo: F. Ramirez de Arellano.

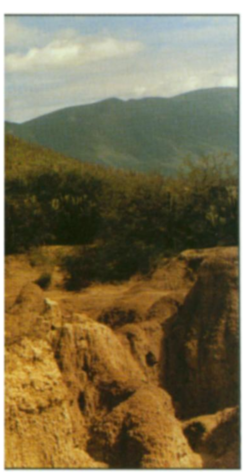
access systems are more likely to exploit natural resources in an unsustainable fashion. However, an individual property system without equity in the distribution of land can generate very inadequate resource allocation between land, labor, and capital.

Semiarid and sub-humid regions in Latin America are subject to three forms of land tenure. Some of the remote and inaccessible regions are still under government ownership, although this form of tenure has been disappearing through privatization programs and land invasion by migrant peasants. Other parts are owned by indigenous communities, who have uncertain tenure, as their ownership claims come from previous countries, and the legal validity of their titles is often challenged by land invaders. Communal ownership is common in many indigenous regions of Mexico, in the mountains in Peru, in parts of the Chaco in Paraguay, and in many parts of the sub-humid and semiarid forests of the Amazon Basin. The third type of land tenure is private property, which is very unequally distributed in most of Latin America. While some large landowners manage very extensive properties, most of the landowners own very small areas which barely cover their needs and are oriented towards subsistence production. Thus, socially the small landowners (*campesinos*) form a group culturally more akin to the indigenous communal landowners. Many large landowners rent their land out to *campesinos* to work under agriculture, and the *campesino* sector functions as the spearhead of deforestation, leaving behind land for larger tenants, more oriented towards animal husbandry than cultivation (13).

In Africa, two contrasting situations occur according to the population pressure. When population is low, the land chief distributes land between farmers. In some situations, where population density is extremely low, the fallow returns to the chief who can redistribute it, thus originating a truly collective type of land management. The drawback is that farmers do not invest in their land, as they have no guarantee that they will profit in the future from their investment. Under this type of tenure, however, there is equity between farmers in access to land and natural resources.

When population density grows and available land has been distributed, the situation changes. Although still under communal tenure, each plot is assigned to one farmer. When the farmer dies or migrates, the land is inherited by his sons or nephews. The land chief retains solely a religious role. Differences in the distribution of land areas between farms can be significant, as inheritance subdivides the land in different ways. The system, however, is not one of private property, as the land belongs to the ancestors, and selling and buying land is rare. Nonetheless, incipient ownership and direct inheritance stimulate investment in the farms, and longer-term agricultural investment in perennial plantations can be observed.

Cattle herders do not have the same access to land (for example the *fulani* and *peul* populations in western Africa). Their rights are limited to access to forage resources, but when the cultivated area becomes larger the herders cannot keep their rangeland. This generates conflicts between herders and farmers, and discourages any investment in rangeland improvement. In Latin America these types of conflicts are rare, as camelid (llama and alpaca) and goat shepherds restrict their grazing activities to open communal ranges in the mountains, where cultivation is not possible.



Migrant farmers do not have the same rights as the indigenous farmers. Their access rights are temporary, they do not have the right to plant trees or engage in long-term agricultural practices, and have little incentive to implement soil conservation practices. This type of tenure is one of the biggest problems in Africa for sustainable land use.

In general, population is increasing in Asia at a similar rate to Africa but there are many different forms of tenancy in Asia; generalizations are difficult. However, throughout the region insecurity of tenure limits the farmer's willingness to invest in land improvement, such as soil conservation practices, and attention must be paid to such issues if SLM adoption is to be enhanced. There should be an indigenous demand for economic and political reform if land reform is to be addressed by external agency assistance. In some countries, e.g., Nepal, Philippines, and Thailand, schemes which allow the planting of plantation crops in return for the rights to cultivate annual crops have been tried but had little success (14). Synthesizing from our Workshop presentations, we conclude that population pressure and land tenure, impact more on SLM in Africa and Asia than in Latin America.

Women can play an important role in cultivating crops. In some African regions most food production is derived from the women's plots because men focus on cash crops. In all cases, women do not own the land. Although greater awareness is being given to gender issues, only a few projects or public institutions are interested in promoting special services for women. They usually have no direct access to extension services and are not allowed to buy inputs. Thus they have little incentive for investment in SLM and these conditions are encouraging the development of extensive agriculture practices.

REVERSING THE SPIRAL OF LAND DEGRADATION

Procedures and Realities

In developing procedures to reverse the spiral of land degradation it is important to recognize that SLM goes beyond biophysical issues. Sustainable land management encompasses the social and economic mechanisms which foster adoption of improved management recommendations. To achieve SLM it is necessary to develop an institutional framework and funding mechanisms conducive to the adoption of SLM practices appropriate for local conditions.

The realities are that farmers' objectives and related land management practices are targeted to food security; optimization of available inputs, including labor; and risk minimization, particularly in resource-poor areas. Also, given that current land management practices result from a complex web of constraints and limitations the linkages are often site specific and poorly understood.

Land-use conflicts arise between range/herders' management and cropland/farmers' management, resulting in nonsustainable land management and limitations to the development of improved land management practices, such as maintenance of permanent vegetative cover, and conservation tillage. Urban development leads to deforestation (for fuelwood for family energy consumption), over-pumping of surface and groundwater resources, and pollution.

A further reality is that land degradation and soil and water quality degradation, and land-cover changes are unevenly documented using biophysical criteria, in terms of the areas degraded as a percentage of total usable area and degree of severity. Because the areas are periodically crippled by drought, it is unclear whether land degradation is a permanent feature or a consequence of transient lack of water. Moreover, the economic and environmental impact of proven land degradation is poorly assessed.

Finally, low soil fertility is at the root of the degradation spiral. Low fertility → low efficiency of use of available water → low vegetative biomass production → a decrease in biological activity as a consequence of the low availability of energetic carbon required to support heterotrophic organisms → poor soil cover, surface crusting, and compaction → runoff → soil erosion → land degradation.

The challenge is to develop SLM through a more efficient use of available resources (human, biological, and solar energy). Many of the procedures for implementing this are known, but there are also major limitations and constraints to its successful achievement.

Constraints (Policies and Institutions)

Sustainable land management encompasses the social and economic mechanisms which foster the adoption of improved management recommendations for the benefit of present and future generations. Adoption is low because of the distortions and failures surrounding herders/farmers which reduce the attraction of sustainable production in terms of income increases. Two major issues can be identified.

(i) Access to and dissemination of relevant information to land users through research and extension of best practices available for SLM and of opportunities for diversification of land use into other income-generating activities, such as fish farming and ecotourism.

(ii) Technological and scientific advances will be instrumental in the transition to sustainable land use, but political, economic, and institutional aspects will also be part of the solution. The market policy, regulatory, and institutional environment is often not conductive to SLM. A combination of mechanisms is required to provide the right incentives to land users; means of enforcement should be applied to specific and local problems related to institutions, markets and equitable participation to take advantage of the disseminated information.

The two issues are closely interrelated but, in the past, the incentives and enforcement component has been neglected as an integral part of SLM and overall land-use policy.

Climatic risk, combined with the high discount rates of land users, institutional and market failures, farm household labor, and cash constraints mean that large-scale adoption of technologies is rare. This hampers development of private sector initiatives in agribusiness, the fertilizer and seed industries, marketing infrastructure, and farmer group associations which are all critical for SLM. It may be necessary, in the short term, to pro-actively stimulate decentralization, promote competition in input and output markets by price liberalization, and improve the capacity building of farmers and water-user associations. Land tenure reform may be a prerequisite for improvements to help resolve land-use conflicts which take place between rangeland herders, foresters, and sedentary cropland farmers. Participatory approaches suggest the need to allow rural communities a greater voice in designing and implementing projects which affect their lives and resources.

REQUIREMENTS AND RECOMMENDATIONS FOR THE FUTURE

The semiarid and sub-humid tropics are regions with a large agricultural potential and are a significant repository of biodiversity. SLM is not only essential for these eco-regions, but also for the common good with regard to carbon sequestration and global climatic change.

Much has been written about SLM, in terms of the biophysical, social, and economic causes of land degradation; the implications for sustainable agricultural productivity; and the requirements for reversing the spiral of land degradation. This has involved the development of frameworks (15) and concept and strategy papers which have added to knowledge, but there is an urgent need to develop strategies and provide practical recommendations which can be used by policy makers. Implementation is now the key issue and we recommend that a series of pilot projects be developed on land which varies in the extent of degradation, in Africa in particular, and which address SLM in a practical way.

It should be emphasized that blanket recommendations for SLM for the semiarid and sub-humid tropics are not possible. As emphasized, there is a heterogeneity of biophysical, social, and economic environments within these regions but it should be possible to formulate a set of policy recommendations which accommodate this diversity and build on indigenous knowledge, as a prerequisite for developing farmer-acceptable technologies for implementing SLM.

Three recommendations have been singled out.

(i) *Assessment of land degradation and sustainability*

The implementation of SLM requires adequate methodology for reliable assessment of sustainability or the probability of sustainability being achieved. The development and use of appropriate indicators for the evaluation of SLM (16) is a starting point for the assessment of land degradation and for the monitoring and evaluation of SLM.

The recent World Bank/FAO/UNDP/UNEP initiative on *Land Quality Indicators* (17) is an important advance. Change in a given indicator can only be measured with respect to time and trend analysis is more important than having absolute values. To reduce the uncertainty generated by year to year variations, long-term data are required and biophysical data should be integrated with full economic accounting and details of changing farm household structures and incomes. It is essential to develop valuation and full cost accounting, including cost-benefit analysis related to investment in land resources, especially in degraded areas. This is particularly relevant in considering re-investment when land resources are degraded beyond their inherent capacity to promote plant growth and buffer environmental changes, such as drought periods and nutrient imbalances. A cost-benefit accounting framework is required which transcends the agricultural sector and encompasses externalities. The long-term experiments required should be conducted at the catchment or community level. If they are supported by simulation modeling and networked, they can form a valuable resource to assess and implement SLM. Because of diversity, site-specific solutions should be developed using a bottom-up approach to develop farmer-acceptable technologies which accommodate this diversity and build on indigenous knowledge. Policies should recognize and involve resource users/managers as active participants in planning, implementing, monitoring, and evaluating these acceptable technologies.

(ii) *Linking biophysical with social and economic information*

A major challenge confronting practitioners who have responsibility for developing recommendations and policies relating to SLM is how to link information relating to the conservation of the resource base, which is a biophysical issue, and the social and economic dimensions. One potentially important area for fruitful interaction and linkage is between the land-user's perceptions of degradation and sustainability, and biophysical assessments. Also, full economic accounting of SLM, including the costs and benefits of on-site and off-site effects which are shared by users, supported by reliable biophysical measurements, should be given high priority. It is also important to link information on farm household asset structures and household incomes and sources to the biophysical data. In this way, the economic pressures which help to cause biophysical degradation can be traced and remedial actions diagnosed.

(iii) *Institutional framework and funding mechanisms*

Institutional strengthening and capacity building at the grassroots level are important issues for the successful implementation of SLM. Whereas a major objective of programs oriented towards sustainability assessment, is to provide managers with better tools for evaluating the impact of development on land quality, they also can be used by institutions at national, regional, and international levels. A recent workshop on "Indicators of Sustainable Development for Decision-Making" (SCOPE-Belgian Costa Rica Workshop, 9–11 January, 1995, Ghent, Belgium) recommended to the *UN Commission on Sustainable Development* that national governments should have the flexibility of selecting appropriate indicators from a core set in developing their own priorities and targets. The question of who provides and who receives financial assistance in establishing cost and risk mechanisms among the different groups who derive significant benefits from an SLM strategy requires attention. These include: (i) farmers and other land users; (ii) other sectors of society; (iii) the global community.

The funding issues are as important as technology development issues to the success of SLM. Because direct land users will only appropriate a fraction of the total social and global benefits, it is unfair to expect them to bear the whole costs. National and international agencies must agree to fund and bear some of the costs.

Previous attempts to implement technologies and strategies for SLM have often failed because the changes proposed have not been adapted to the social, economic, and political conditions in the regions threatened by unsustainability. The need to incorporate land-user needs, through a participatory approach and decision making constraints into the SLM research agenda is a high priority. There is a need to develop information production and sharing mechanisms, preferably linked with agri-business, for technology development, marketing, and distribution, to provide land users and other stakeholders with the tools for making the best decisions.

The potential beneficiaries of enhanced SLM performance in the semiarid and sub-humid tropics are many. All stakeholders have much to gain from a ground-level strategy through a multidisciplinary and participatory approach. These include:

(i) land users in relation to an increased return on investment, intergenerational equity, and an improvement in the quality of life;
(ii) the scientific community in terms of priority setting which gains in credibility with decision-makers and funding agencies through a bottom-up approach; and finally
(iii) policy makers and funding agencies with respect to the impact of choices made and money invested *vis à vis* poverty alleviation, equity, and environmental management.

Global environmental change introduces a new paradigm for SLM (18). Possible changes in climate, acidic deposition, and ground-level photochemical ozone levels may make current technologies for SLM less successful in the longer term.

Nevertheless, international funding agencies are in a strong position to influence the direction of development and the extent to which SLM can be promoted and implemented at the national level. Just as environmental impact assessment is now an integral part of development project evaluation, so impacts on land management sustainability should also be an essential feature of the appraisal of any development program.

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Keith Syers is professor of soil science at the University of Newcastle upon Tyne and Director of the recently established Newcastle International Centre for Sustainable Agriculture. He was previously Director of Research at the International Board for Soil Research and Management based in Bangkok, Thailand. His address: Newcastle International Centre for Sustainable Agriculture, Faculty of Agriculture and Biological Sciences, University of Newcastle, Newcastle upon Tyne, NE1 7RU, UK.

John Lingard is senior lecturer in agricultural economics at the University of Newcastle upon Tyne and assistant director of the Newcastle International Centre for Sustainable Agriculture. He has worked as a consultant to the World Bank, FAO, IRRI, ODA, the EU, and the Asian Development Bank. His address: Department of Agricultural Economics and Food Marketing, Faculty of Agriculture and Biological Sciences, University of Newcastle, Newcastle upon Tyne, NE1 7RU, UK.

Christian Pieri is an agro-ecologist working in the Department of Agriculture and Natural Resources of the World Bank. He is providing expertise and support to World Bank financed projects, particularly with respect to the development of sustainable land management and conservation tillage practices under tropical and warm conditions. He is currently in charge of the international program on Land Quality Indicators, an initiative developed with FAO, UNDP, UNEP, CGIAR and bilateral organizations. His address: Agriculture and Forestry Systems Division, The World Bank, Washington, D.C. 20433, USA.

Exequiel Ezcurra is a researcher at the Centre of Ecology, Universidad Nacional Autónoma de México. His main areas of interest are the conservation of natural resources, the ecology of arid zones in Latin America, the biogeography of desert plants, and the management of natural resources in areas under traditional, indigenous use. His address: Centro de Ecologia, UNAM, Apartado 70-275, 04510 México, D.F., Mexico.

Guy Faure is a tropical agriculture scientist with special interest in agroeconomics. He is in charge of a research program 'Farming Agriculture in the Savanna Region' at Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD). His address: CIRAD, BP 5035, 34 032 Montpellier Cedex, France.

