Conserving land

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15 Conserving land—protecting water

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Overview

The key to effective management of water resources is understanding that the water cycle and land management are intimately linked. Every land-use decision is a water-use decision. Improving water management in agriculture and the livelihoods of the rural poor requires mitigating or preventing land degradation. Erosion, pollution, nutrient depletion, reduced plant cover, loss of soil organic matter, and other forms of degradation resulting from faulty agricultural land-use decisions threaten ecosystems, change regional and global hydrological cycles, and have enormous negative implications for water productivity, quantity, quality, and storage *[well established]*. Up to half the world's agricultural land and half its river systems are now degraded to some degree *[established but incomplete]*. The chief cause of land degradation is the unsuitable use of agricultural land. Because 80% of the world's poor rely directly on agriculture, degradation is particularly deleterious to small-scale farmers in developing countries. For farming communities key issues are declining returns to labor; the impacts of land degradation on human health, including rising malnutrition rates; and the increasing pollution of drinking water.

Land degradation is driven by the complex sociopolitical and economic context in which land use occurs. Policy and livelihood decisions that fail to account for the long-term relationships between processes and consequences drive degradation. Sociopolitical and economic systems often result in insecure land tenure, political environments can discourage innovation and adaptation, and inequitable gender relationships often distance resource users from management decisions. In some cases development projects insist on land husbandry techniques that are ill-suited to the environment and poorly matched to local capacity. In other cases suppression of innovation may be more subtle—innovation is an expression of freedom that may sit uneasily with dominant political thought.

Smallholder agricultural systems are an important intervention point for measures aimed at preventing or mitigating land degradation in the developing world. Smallholder agriculture is the mainstay of most developing country rural economies and is likely to remain so into the foreseeable future. In many vulnerable areas smallholder farmers possess the greatest unexploited potential to directly influence land- and water-use management. Smallholders make up the majority of the world's rural poor and often occupy marginal and vulnerable land. It makes sense, therefore, to concentrate development and conservation investments in land and water sectors and human capacity at this level. Supporting small-scale agriculture probably offers the best chance for achieving many of the Millennium Development Goals in developing countries.

> In many vulnerable areas smallholder farmers possess the greatest unexploited potential to directly influence land- and water-use management

Integrated solutions that support participation in sustainable land management are needed to achieve balance in food production, poverty alleviation, and resource conservation. Policy and administrative actions are needed to create sociopolitical environments conducive to good governance and to activities that combat and mitigate land degradation. They are also needed to support such initiatives through appropriate technologies, integrating soil and water management, marketing infrastructure, and institutional environments. Traditional land-use systems are not static. Provided that the opportunity and enabling environment exist, land users can alter their land husbandry techniques to ameliorate or even reverse land degradation. Many useful lessons can be drawn from success stories involving both traditional methods of cultivation and local innovation and providing a basket of options for land users. Sustainable increases in land and water productivity are possible through resource-conserving agricultural approaches that can increase the resilience of systems otherwise susceptible to extreme climate events and climate variability. This is important, because it can reduce the vulnerability and uncertainty to which the rural poor are frequently exposed.

Enhancing the multifunctionality of agricultural land is a point of convergence for poverty reduction, resource conservation, and international concerns for global food security, biodiversity conservation, and carbon sequestration. Too much land-use policy and research fails to appreciate the interlinked nature of landscapes. Addressing land degradation from the individual farm up to the landscape level requires a series of integrated measures that focus on resource-conserving farming strategies and on sustainable soil and water productivity. Ecoagricultural approaches can create synergies among agricultural production, water, and wild biodiversity, benefiting ecosystems as a whole. Integrated land and water management drawing on such strategies has carbon sequestration and clean water benefits *[well established]*, although the quantitative and site-specific evidence is still incomplete.

Research is needed to underpin and stimulate the development of land-use systems that can absorb and sustain high population densities. The global population is unlikely to stabilize soon, with the highest population growth occurring in developing countries. Although opinions differ, population growth is not necessarily synonymous with land and water degradation. In many places, population growth has led to land-improving investments and conservation management. National efforts to address this issue must couple population policies with research on land-use systems that can accommodate high population densities by increasing labor productivity and wealth generation per parcel of land. Rigorous measurement of land and water interactions, especially at watershed scales, is required to understand the drivers of land degradation, to identify appropriate ways to manage them, and to assess the impact of previous interventions.

Key elements of land degradation

The Global Assessment of Human-Induced Soil Degradation (GLASOD), conducted during the 1980s, was the first attempt to estimate the extent of soil degradation globally (Oldeman, Hakkeling, and Sombroek 1991) and remains today the only uniform global source of degradation data. GLASOD paints a stark picture (box 15.1). According to GLASOD estimates, degradation of cropland appears to be most extensive in Africa, affecting 65% of cropland areas, compared with 51% in Latin America and 38% in Asia. Degradation of pasture is also most extensive in Africa, affecting 31% of pasturelands, compared with 20% in Asia and 14% in Latin America. Forestland degradation is most extensive in Asia, affecting 27% of forestlands, compared with 19% in Africa and 14% in Latin America. Based on GLASOD, Wood, Sebastian, and Scherr (2000) estimate that 40% of agricultural land in the world is moderately degraded and a further 9% strongly degraded, reducing global crop yield by 13%. In 1992 the UN Convention to Combat Desertification, supported by GLASOD's findings and concentrating particularly on

box 15.1 The Global Assessment of Human-Induced Soil Degradation—the first global assessment

The Global Assessment of Human-Induced Soil Degradation (GLASOD) project set out to map global soil degradation in the 1980s (Oldeman, Hakkeling, and Sombroek 1991). The assessment was based on expert opinion—experts' assessments of the status of soil degradation in the countries or regions with which they were familiar. The final statistics, based on continental trends worldwide, revealed that erosion by water is the most prominent degradation feature worldwide (see table). Other causes, accounting for smaller areas of degradation, are various forms of chemical deterioration, such as soil fertility decline and soil pollution, and physical deterioration, such as compaction and waterlogging. The GLASOD study was the first comprehensive soil degradation overview at the global scale. It raised awareness of various further needs, still relevant today:

- An assessment of measures to control degradation.
- A more objective, quantitative approach (especially for more detailed scales).
- Data validation and updating.

GLASOD had several limitations. It was too large for national-level breakdowns. It was based on qualitative and subjective expert judgment, with perhaps too much emphasis on visible and spectacular land degradation problems, such as erosion. And it was too problem focused.

Since GLASOD there have been some regional studies, such as the Assessment of the Status of Human-Induced Soil Degradation in South and South East Asia (van Lynden and Oldeman 1997) and the World Atlas of Desertification (Middleton and Thomas 1997). The Land Degradation Assessment in Drylands project is expected to provide more land degradation data in the future.

(continues on next page)

box **15.1** **The Global Assessment of Human-Induced Soil Degradation—the first global assessment** (continued)

Human-induced soil degradation for the world
(millions of hectares)

Type	Light	Moderate	Strong	Extreme	Total
Water	343.2	526.7	217.2	6.6	1,093.7 (55.6)
Loss of top soil	301.2	454.5	161.2	3.8	920.3
Terrain deformation (such as gully formation)	42.0	72.2	56.0	2.8	173.3
Wind	268.6	253.6	24.3	1.9	548.3 (27.9)
Loss of top soil	230.5	213.5	9.4	0.9	454.2
Terrain deformation (such as dune formation)	38.1	30.0	14.4	—	82.5
Overblowing	—	10.1	0.5	1.0	11.6
Chemical	93.0	103.3	41.9	0.8	239.1 (12.2)
Loss of nutrients	52.4	63.1	19.8	—	135.3
Salinization	34.8	20.4	20.3	0.8	76.3
Pollution	4.1	17.1	0.5	—	21.8
Acidification	1.7	2.7	1.3	—	5.7
Physical	44.2	26.8	12.3	—	83.3 (4.2)
Compaction	34.8	22.1	11.3	—	68.2
Waterlogging	6.0	3.7	0.8	—	10.5
Subsidence organic soils	3.4	1.0	0.2	—	4.6
Total	749.0 (38)	910.4 (46)	295.7 (15)	9.3 (1)	1,964.4 (100)

— zero or negligible

Note: Numbers in parentheses are percentages of totals. A *light* degree of soil degradation, implying somewhat reduced productivity but manageable in local farming systems, is identified for 38% of all degraded soils worldwide. A somewhat larger percentage (46%) has a *moderate* degree of soil degradation, with greatly reduced productivity. Major improvements, often beyond the means of local farmers in developing countries, are required to restore productivity. More than 340 million hectares (ha) of this moderately degraded terrain are found in Asia and more than 190 million ha in Africa. Some 15% of degraded soils are *strongly* degraded. No longer reclaimable at the farm level and virtually lost, they will require major engineering work or international assistance to restore them. Some 124 million ha are in Africa and 108 million ha in Asia. *Extremely* degraded soils are considered irreclaimable. They make up about 0.5% of total degraded soils worldwide, of which more than 5 million ha are in Africa.

Source: Oldeman, Hakkeling, and Sombroek 1991.

desertification, was signed at the United Nations Conference on the Environment and Development. While land degradation is not confined to desertification (box 15.2), this convention placed land degradation processes firmly on the global agenda for addressing negative environmental trends. Estimates of land-use degradation *rates* are even more uncertain than estimates of the extent of degradation, varying from 5 to 10 million hectares a year (Scherr and Yadav 1996).

The root cause of land degradation is poor land use. Land degradation represents a diminished ability of ecosystems or landscapes to support the functions or services required for sustaining livelihoods. When agriculture is introduced in place of natural vegetation and

box 15.2 | What is desertification?

Desertification does not simply mean "expanding deserts" but covers a more complex concept. The United Nations Convention to Combat Desertification defines it as the degradation of land in arid, semiarid, and subhumid dry areas caused by climate change and human activities. It is accompanied by a reduction in the natural potential of the land and a depletion of surface water and groundwater resources. The phenomenon is global in scope, threatening about two-thirds of the countries of the world and one-third of the earth's surface on which a fifth of the world population lives. The vulnerability of land to desertification is due mainly to climate, land relief, the state of the soil and the natural vegetation, and the ways these two resources are used by farmers and pastoralists. Because many of the poorest land users live in drier areas, programs to combat desertification simultaneously address poverty.

is then intensified to maximize yields, farmers simplify agroecosystem structures by limiting the variety of vegetation. Such vegetation changes immediately affect water use and cycling in landscapes and result in biodiversity loss and the development of a less complex network of ecosystem interrelations than occurs naturally (see chapter 6 on ecosystems). Over time, continuing agricultural production, particularly on marginal or fragile lands, results in degradation of the natural resource base, with increasing impacts on water resources.

This section considers primarily the relationships between major forms of soil degradation and water:

- *Loss of organic matter and physical degradation of soil.* Soil organic matter is integral to managing water cycles in ecosystems. Depleted levels of organic matter have significant negative impacts on infiltration and porosity, local and regional water cycles, water productivity, plant productivity, the resilience of agroecosystems, and global carbon cycles.
- *Nutrient depletion and chemical degradation of soil.* Pervasive nutrient depletion in agricultural soils is a primary cause of decreasing yields, low on-site water productivity, and off-site water pollution. Salinity, sodicity, and waterlogging threaten large areas of the world's most productive land and pollute groundwater.
- *Soil erosion and sedimentation.* Accelerated on-farm soil erosion leads to substantial yield losses and contributes to downstream sedimentation and the degradation of water bodies, a major cause of investment failure in water and irrigation infrastructure.
- *Water pollution.* Globally, agriculture is the main contributor to non-point-source water pollution, while urbanization contributes increasingly large volumes of wastewater. Water quality problems can often be as severe as those of water availability, but have yet to receive as much attention in developing countries.

Loss of organic matter and physical degradation of soil

Soil organic matter is integral to managing water cycles in ecosystems. Among the best documented examples are organic matter losses that occur when land is cleared of forest and farmed intensively—especially when accompanied by burning—and productivity declines rapidly. Less visible is the loss of organic matter through interrill erosion, a process


Photo 15.1 Cultivated hillside in Mexico with rill erosion

that selectively removes organic matter and inorganic nutrient-rich particles, leaving impoverished topsoil behind. The impact of organic matter loss is not confined to production loss, but also disturbs water cycles.

The decrease of soil organic matter, along with the associated decline of faunal activities (aggravated by the use of pesticides and tillage practices), favors the collapse of soil aggregates and thus the crusting, and sealing, of the soil surface (Valentin and Bresson 1997). The result is reduced porosity, less infiltration, and more runoff. Compaction of the soil surface, by heavy machinery or overgrazing, for example, can cause overland flow, even on usually permeable soils (Hiernaux and others 1999). Such changes increase the risk of flooding and water erosion. On sloping terrain, intense rainfall and associated runoff increase interrill erosion (photo 15.1). Higher runoff concentrates in channels, causing rills and then gullies.

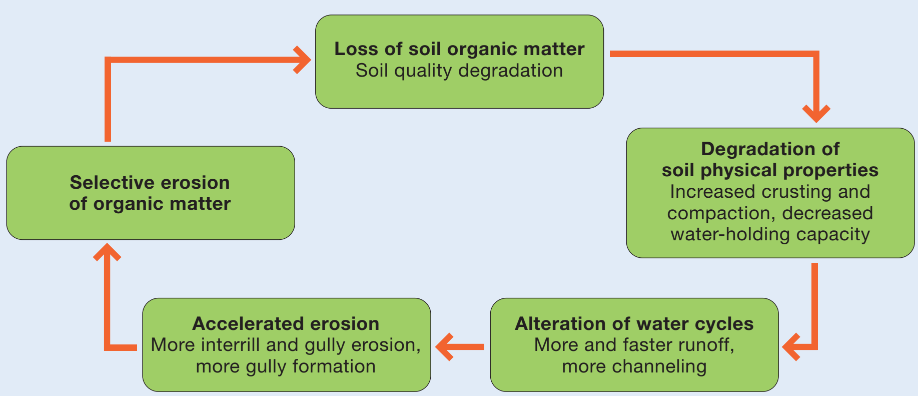
Degradation thus changes the proportion of water flowing along pathways within catchments, with a tendency to promote rapid surface overland flow (runoff) and decrease subsurface flow. In pristine or well managed environments higher infiltration rates are the norm. As these environments are degraded, a negative, self-accelerating feedback loop is created (figure 15.1).

By controlling infiltration rates and water-holding capacity, soil organic matter plays a vital function in buffering yields through climate extremes and uncertainty. Significantly, it is one of the most important biophysical elements that can be managed to improve resilience. Soil organic matter, furthermore, holds about 40% of the overall terrestrial carbon pool—twice the amount contained in the atmosphere (Robbins 2004). Poor agricultural practices are thus a significant source of carbon emissions and contribute to climate change.

Nutrient depletion and chemical degradation of soil

One-way nutrient flows occur from forest to farm, from rural to urban areas, from terrestrial ecosystems to the ocean and increasingly even across continents (Craswell and others

figure **15.1** **A negative cycle of soil-water relationships leads to increasing degradation**



2004). This results in nutrient depletion at the sources and pollution at the sinks. Closing some of these loops will be vital, especially as urbanization continues and these imbalances in nutrient movement accelerate (Vlek 2005).

Globally, only half of the nutrients that crops take from the soil are replaced. This depletion of soil nutrients often leads to fertility levels that limit production and severely reduce water productivity. Shorter fallow periods do not compensate for losses in soil organic matter and nutrients, leading to the mining of soil nutrients. For instance, in southern Mali an estimated 40% of farmers' incomes come from soil mining, while only 11% of gross income is reinvested into agricultural production (Steiner 1996). In many African, Asian, and Latin American countries, the nutrient depletion of agricultural soils is so high that current agricultural land use is not sustainable (Craswell and others 2004). Nutrient balance analysis demonstrates nutrient depletion in many Asian countries on the order of 50 kilograms (kg) of macronutrients per hectare per year (Sheldrick, Syers, and Lingard 2002).

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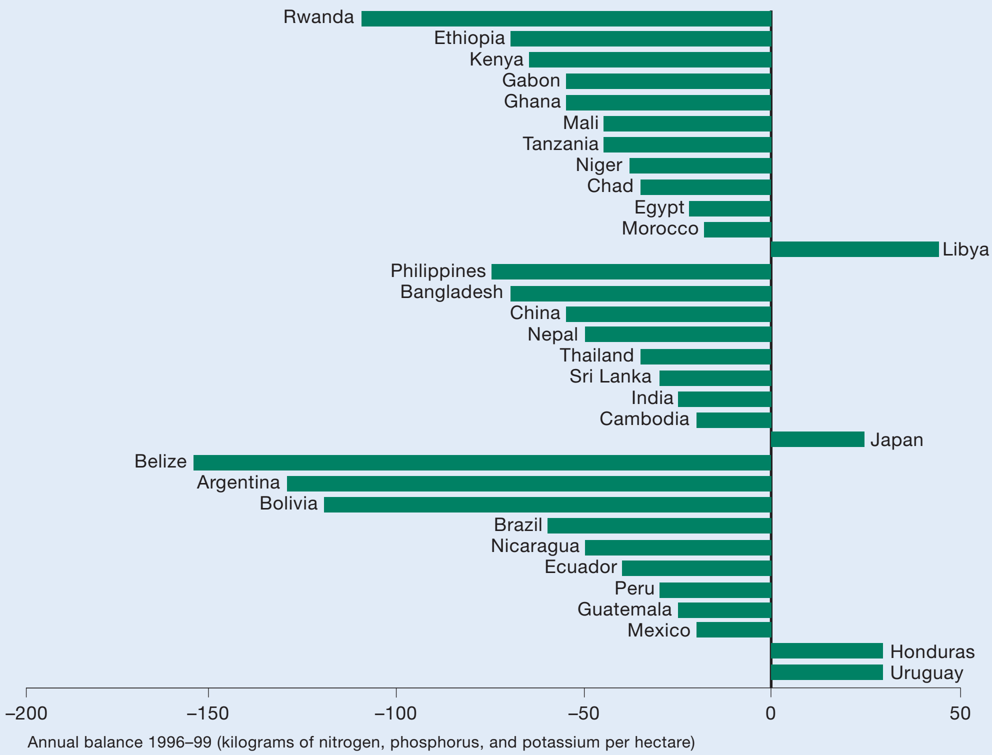
Trends are even worse in Africa, where nutrient depletion in some East and Southern African countries is estimated to average 47 kg of nitrogen, 6 kg of phosphorous, and 37 kg of potassium per hectare a year (figure 15.2; Smaling 1993; Stoorvogel, Smaling, and Jansen 1993). Country averages hide important site-specific variation. Where farmers are poor and cannot afford inputs to replenish fertility, nutrient loss through soil mining (and selective erosion) is much higher. Nutrient depletion is now considered the chief biophysical factor limiting small-scale farm production in Africa (Drechsel, Giordano, and Gyiele 2004).

Other important forms of chemical degradation are the depletion of trace metals such as zinc, causing productivity declines and affecting human nutrition (Cakmak and others 1999; Ezzati and others 2002), acidification, and salinization. Secondary salinization is a serious threat to sustainable irrigated agricultural production. Although data are poor, estimates indicate that 20% of irrigated land worldwide suffers from secondary salinization and waterlogging (Wood, Sebastian, and Scherr 2000) induced by the build-up of salts introduced through irrigation water (see chapter 9 on irrigation).

Soil erosion and sedimentation

Soil erosion rates almost always rise substantially with agricultural activity. This is especially the case with annual systems, where the soil surface is seasonally exposed to rainfall and wind. With a fivefold increase in the global area under crop production and livestock grazing over the past 200 years, this has become a serious problem, both onsite and downstream.

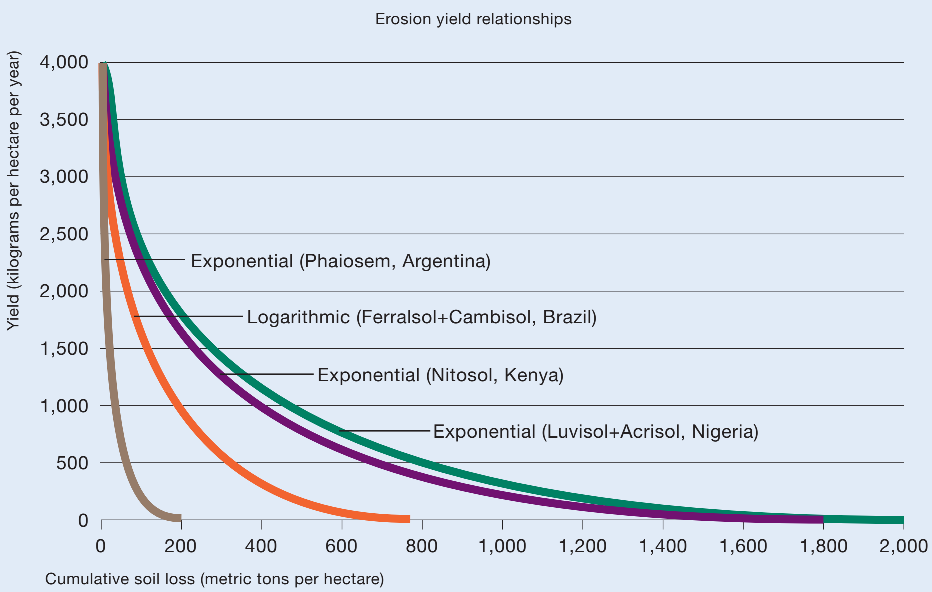
Onsite, soil erosion reduces crop yields by removing nutrients and organic matter. Yield impacts can be severe and vary with soil type. They are particularly evident in the early stages of erosion. In Ethiopia soil erosion reduces yields by an average of 1%–2% annually, although over 20 years of observation base yields have not fallen below 300–500 kg per hectare (Hurni 1993). Stocking (2003), however, demonstrated much more dramatic declines on a wide range of soils (figure 15.3). Erosion also interferes with soil-water relationships: the depth of soil is reduced, diminishing water storage capacity and damaging figure **15.2** **Nutrient balance estimates for selected countries in Africa, Asia, and Latin America show nutrient depletion in many countries**



Source: Craswell and others 2004: Sheldrick, Syers, and Lingard 2002.

soil structure, thus reducing soil porosity. Surface sealing and crusting reduce infiltration and increase surface runoff, which is a problem in itself and results in a net loss of water for crops.

Downstream, the main impact of soil erosion is sedimentation, a major form of human-induced water pollution. The increased sediment load in rivers can create important practical and economic problems, such as the sedimentation of reservoir navigation channels and the impairment of turbines, irrigation schemes, and water treatment facilities. Sedimentation causes storage loss within the world's major reservoirs at a rate of 1% of gross capacity a year. The effects on small dams and reservoirs can be even more acute. In Tigray, Ethiopia, most of the reservoirs built to improve the livelihoods of poor people lost more than half their water storage capacity within five years of entering service due to sedimentation arising from erosion in upper catchments, although the dams had a designed life of 20 years (Lulseged 2005). In response, the government has all but stopped its dam building activities in Tigray (Vlek 2005). An estimated 25% or more of the world's figure **15.3** **Erosion results in large yield declines for a selection of tropical soils**



Source: Stocking 2003.

freshwater storage capacity will be lost in the next 25–50 years unless measures are taken to control sedimentation in reservoirs (Palmieri, Shah, and Dinar 2001).

Controlling sedimentation in large reservoirs requires soil conservation at the catchment scale. Because sediment sources vary considerably, a variety of strategies may be required. In the Himalayan region, as in other tectonically active zones, mass wasting processes—landslides (most of them natural, others triggered by poor road construction practices), riverbank erosion, and gullies—contribute far more sediment than do the hill farmers who have historically received the blame (Ives and Messerli 1989). Under certain circumstances gully erosion is the main source of sediment at the catchment scale and is usually triggered or accelerated by a combination of poor land use and extreme rainfall (Lulseged 2005). Poorly maintained or degraded pastures can also contribute substantially to sedimentation in some areas. Although erosion rates may be lower than from cropland, pasture areas are often much larger (see chapter 13 on livestock).

Water pollution

Every day more than 2 million metric tons of waste are dumped into rivers and lakes (WWAP 2003). There are now about 12,000 cubic kilometers of polluted water on the planet, a volume greater than the contents of the world's 10 biggest river basins and equivalent to six years' worth of global irrigation needs. In India less than 35% of wastewater receives primary treatment, and there is little if any treatment in smaller cities and rural areas. Scenarios are similar—if not worse—in other developing countries.

Recent assessments (WWAP 2003; MEA 2005; UNEP 1999, 2004) detail alarming trends in pollution of the world's freshwater and emphasize the destructive effects of eutrophication caused by increased anthropogenic nitrogen and phosphorus loading and increasing pollution by pesticides, heavy metals, and bacteria, among other pollutants. Many of this second group of agents are persistent and can have human health impacts even in very low concentrations and over long periods of time.

Agricultural activities can exacerbate pollution problems by increasing the proportion of water that flows rapidly over land

Agricultural activities can exacerbate these problems by increasing the proportion of water that flows rapidly over land. Surface runoff picks up microbes, nutrients, organic matter, pesticides, and heavy metals, which tend to concentrate in surface layers. Phosphorus, for example, can be approximately 10 times higher in surface runoff than in groundwater (Gelbrecht and others 2005). Agricultural chemicals—pesticides, herbicides, and fertilizers—are also readily transported by runoff and drainage water or may infiltrate groundwater. The destruction of riparian forests, wetlands, and estuaries allows unbuffered flows of nutrients between terrestrial and water ecosystems. Excess nutrients leak into groundwater, rivers, and lakes and are transported to the coast.

Drivers of land degradation

Linked sociopolitical, economic, demographic, and biophysical drivers of land degradation have resulted in the accelerated degradation of resources and diminished ecosystem resilience. Three key drivers are considered here:

- *Sociopolitical and economic drivers.* People make decisions about water and land use based on sociopolitical and economic contexts, as well as the physical characteristics of land. Land tenure, markets and commodity prices, and gender relations all affect decisionmaking. In addition, political environments may be so repressive as to undermine the readiness of land users to develop and implement innovative land and water management practices.
- *Demographic trends.* Under certain circumstances high and growing population densities can have serious impacts on water and land. This is particularly evident where populations spill over into previously uncultivated marginal dry lands (as has been happening rapidly in parts of East Africa) and where poor farmers are pushed further uphill onto ever steeper slopes (as is the case in parts of Asia and Central America). In both cases this land is especially vulnerable to degradation.
- *Biophysical forces.* Major biophysical events, such as hurricanes, cyclones, and tectonic activity, probably have a greater role to play in land degradation than previously believed. Usually, such events have a considerable impact on poor people, who live in more vulnerable areas and who are less able to recover from these events.

Sociopolitical and economic drivers

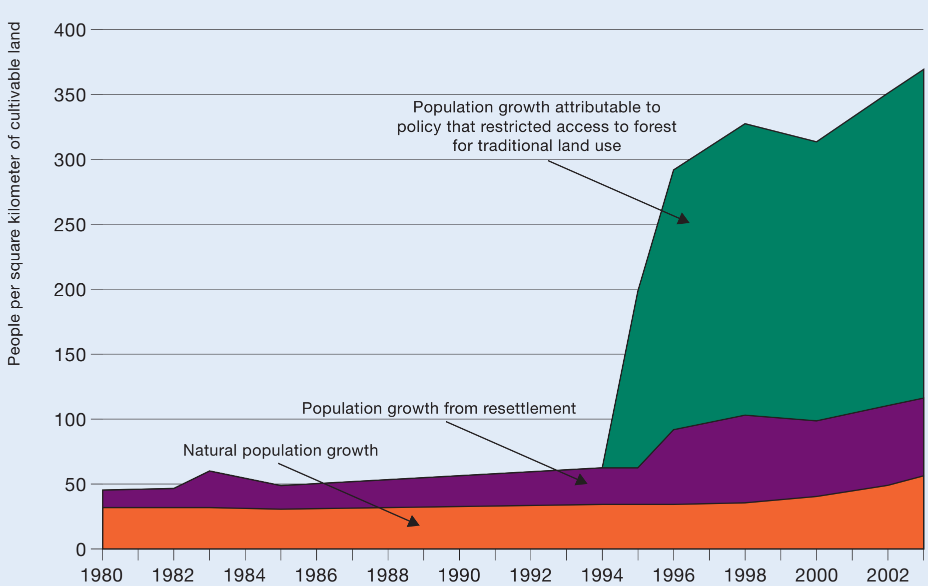
The sociopolitical and economic factors that influence human decisionmaking about land use are deeply intertwined. Together, they determine which people and how many of them inhabit and use what land and how access to resources is defined, negotiated, and managed. The ways national and regional policies are articulated at local levels are often unanticipated and may have profound impacts on land use and concomitant degradation (see Blakie 1985 for pioneering work on this topic). In many cases policies addressing land use push vulnerable sections of the population on to the poorest land, which is particularly vulnerable to degradation.

Misguided policy may have unintended effects. In Lao PDR the average population density is less than 15 inhabitants per square kilometer. In one representative village in the north, however, natural growth coupled with resettlement and conservation policies has led to a population density exceeding 350 inhabitants per square kilometer of arable land (figure 15.4). Land degradation in these resettlement areas has been severe (Lestrelin, Giordano, and Keohavong 2005). Policy influences on land use and degradation tend to be more nuanced, but examples as extreme as this are not altogether uncommon (Homewood and Brockington 1999; Wily 1999).

In Mexico, as in many other areas of the developing world, there is a clear tendency for poorer rural communities to be located on sloping lands (figure 15.5; see also photo 15.1). Policies favor the nonpoor, 80% of whom inhabit more desirable flat lands, while 66% of the rural poor live on lands with a greater than 5% slope (Bellon and others 2005).

figure **15.4** **Resettlement programs and policies that restrict access to land have had enormous impacts on population density in a village in Northern Lao PDR**

Population density attributable to natural growth, resettlement, and land reclassification, 1976–2003

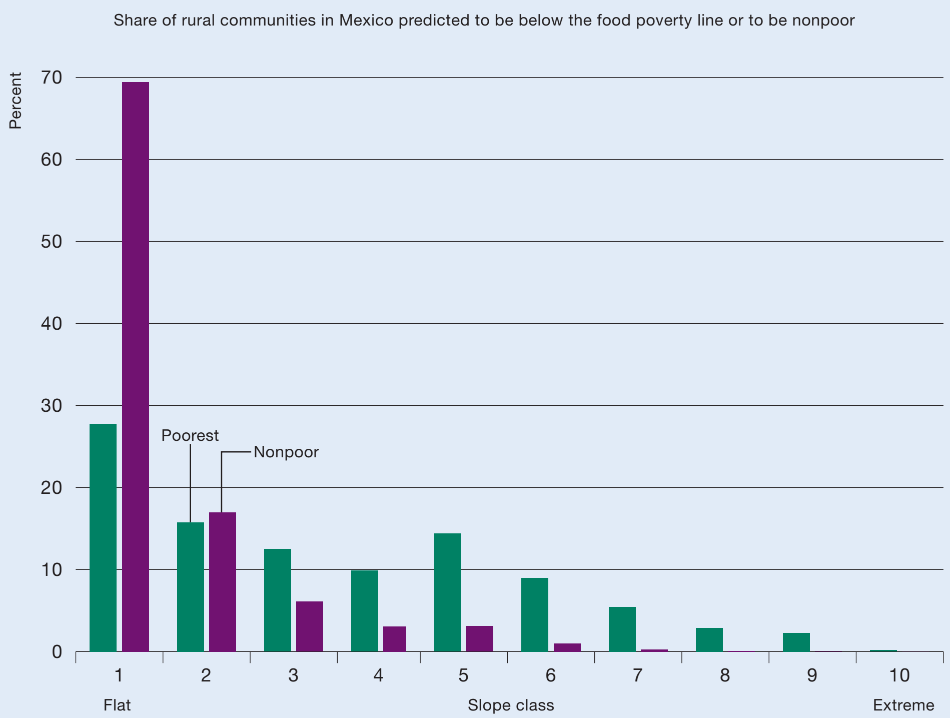


Source: Lestrelin, Giordano, and Keohavong 2005.

Policymakers need to anticipate such consequences if they are to prevent a further spiral of land degradation and poverty.

The type of tenure system often influences how land is managed and used (McCay and Acheson 1987; Berkes 1989). Well functioning common property regimes are governed by widely agreed land management practices and rules, with no free-riding by resource users. Competition among community users is low, and cooperation is high (McCay and Acheson 1987). But where no governance mechanisms are in place or where they have broken down, open-access conditions may arise, leading to "tragedy of the commons" scenarios (Hardin 1968). The result is almost always overexploitation and degradation. Among natural resources examples are global fisheries and denuded parts of the Amazon forest. Competition between users, especially for access to resources, may be expressed through violence (box 15.3). Where small-scale mixed farming is the dominant form of land use, investments in sustainable land management are most likely where there is security of tenure, which means security of access, although not necessarily private ownership.

figure **15.5** | **In rural Mexico most of the poor live on sloping land and most of the nonpoor live on flat land**



Source: Bellon and others 2005.

box 15.3 Violence as a livelihood strategy among pastoralists in northern Kenya

The pastoralists of northern Kenya, which include the Borana, Rendille, Samburu, and Turkana, graze their cattle in an area that is underadministered and whose borders with neighboring Somalia, Sudan, and Uganda are porous. Improvements in veterinary medicine and disease control have ensured that for many pastoral communities, herds experience less disease, increased lifespan, and improved survival under difficult conditions. Herd sizes have increased, so that traditional boundaries separating ethnic groups are under severe pressure as herders seek new grazing areas.

Unrest in Somalia, southern Sudan, and northeastern Uganda, much of which has continued for decades, has meant that the struggle to obtain additional grazing is now assisted by modern weaponry. During periods of drought or Kenya's dry season, armed conflict ("AK47 herding") between the region's ethnic groups and nomads from neighboring countries is common (Gray and others 2003). Such raiding is intended not only to secure grazing but also, as has traditionally been the case, to rustle cattle. For the victorious raiders, these raids can improve livelihoods considerably by ensuring additional cattle and opening up new grazing. For the attacked, however, the raids can have very serious consequences for their livelihoods. Because raiding is so common in this part of the world, it plays a pivotal role in the success or failure of livelihood strategies here (Hendrickson, Armond, and Mearns 1998).

Relations between men and women are a key component of the sociopolitical conditions that underpin land and water use. Women produce nearly all the food in developing countries. Women constitute up to 90% of the rice-producing labor force in Southeast Asia and produce up to 80% of basic household food stuffs in Sub-Saharan Africa, where they make a similar contribution to the agricultural labor force (Lado 1992). Despite women's major contribution to cultivation, harvesting, and processing, men—particularly in Africa—retain most ownership, control, and decisionmaking power over agricultural resources—and even over women's labor (Ellis 2000).

Many parts of the developing world are in a state of transition between an economy dominated by subsistence objectives to a cash and surplus production economy. As cash income assumes a more prominent role in households, many rurally based men migrate to find wage labor, leaving women a greater share of household agricultural responsibilities (von Bulow and Sørensen 1993; Francis 1995). Yet traditional patterns of land ownership and access remain, leaving women with principal responsibility for farming but few decisionmaking powers. As the cash economy grows, more of women's labor is taken up growing cash crops controlled by men, potentially taking female labor away from food production and giving men even greater control over the product of women's labor (von Bulow and Sørensen 1993; Mearns 1995).

The result is that women, who have the most intimate relationship with the land and who are best positioned to manage it on a daily basis, are often excluded from decisions that affect its use. Paradoxically, women may be even better at land husbandry than men (see box 15.7 later in the chapter). Where higher yields are seen to be generated mainly by men, yield differences are the result mainly of gender inequalities in access to agricultural inputs. In Sub-Saharan Africa women have less access to education (including agricultural training) and to cash for inputs such as fertilizers than do men. Therefore, unequal assets could have a greater impact on food and nutrition security in this region than in others. In Burkina Faso men have greater access to fertilizer and to household and nonhousehold labor for their farm plots. Reallocating these resources to women could increase household agricultural output by 10%–20% (Alderman and others 2003). In Kenya, if female farmers had the same levels of education, experience, and farm inputs as their male counterparts, their maize, bean, and cowpea yields could increase by 22% (Alderman and others 2003).

> Because women have less control over land than men, this may have profound implications for household nutrition

Because women have less control over land and what is cultivated on it, this may also have profound implications for household nutrition. The role of women in rearing livestock and marketing livestock products is equally important for household food security (see chapter 13 on livestock). As the primary caregivers in the developing world, women, through their access to food, may also determine children's nutritional well-being.

Demographic drivers

Land degradation is rarely a problem under conditions of low population pressure and high per capita resource abundance. But land degradation accelerates as population increases, a process often attributed to the breaching of the land's "carrying capacity" by excess populations of people and their livestock. The relationship between population pressure and land (and other resource) degradation is controversial, however, and spans Malthusian thinkers who insist on a positive correlation (Ehrlich 1968), to others who emphasize that rising populations can trigger innovation in land management (a perspective initially advanced by Boserup 1965; see also Tiffen, Mortimore, and Gichuki 1994; Scherr 1999). If conditions are conducive, high population densities can stimulate conservation and good land husbandry.

In the absence of conducive conditions, however, high population densities can represent a serious problem (box 15.4). Despite the trend toward urbanization, populations are still increasing in most rural areas of developing countries, and the consequences are

box 15.4 **Contrasting examples of population growth and land degradation from Africa**

Using current relations between soil erosion and population growth, Planchon and Valentin (forthcoming) calculated that West Africa's degraded area would increase by 202,000 square kilometers over the next 30 years, a 13% increase in the area occupied by degraded soils. The area affected by water erosion would increase 26%, mainly in the moist savannah zone (1,000–1,500 millimeters of annual rainfall). Although far less densely populated than the wettest region, many areas in the moist savannah may have a population density exceeding 70 inhabitants per square kilometer, which is a critical threshold in a region vulnerable to severe water erosion. In the wettest zone (more than 1,500 millimeters of annual rainfall), pristine areas are expected to erode abruptly as a result of land clearing using heavy machinery (Valentin 1996).

In contrast, Reij, Scoones, and Toulmin (1996) have demonstrated that in response to increased population pressure, farmers in parts of Burkina Faso have invested substantially in improving their natural resource base. The result, associated with an upturn in rainfall, has been a remarkable recovery in vegetation and conservation status over the last decade or so.

typically a reduction in plot size and spillovers onto marginal lands, such as steep hillsides or areas with poor or erratic rainfall. Larger rural populations make more demands on resources, and this is exacerbated by the parallel growth in urban inhabitants. Together, these ingredients can result in serious land degradation.

Too few farmers can also result in problems. When young farmers move to urban areas, the agricultural labor pool shrinks, making maintenance of structures such as terraces and irrigation channels uneconomical. Ancient terracing systems may collapse (Critchley, Reij, and Willcocks 1994). Analysis of the relationship between degradation and population in the Machakos District of Kenya suggests that a minimum population density is required for development to take off; if the number is too low, investments do not pay off and resource degradation continues (Templeton and Scherr 1999).

The complex relations among growing population density, the context within which it occurs, and land degradation are not well understood. For now, most interventions designed to mitigate land degradation are based on the premise that high and growing population density constitutes a key driver of land degradation.

Few land-use systems will be able to adjust to the impacts of climate change, and new systems will have to evolve to cope with disturbed rainfall patterns

Biophysical drivers

Natural fluctuations in weather patterns (such as the El Niño/La Niña phenomena) resulting in extreme events occur regardless of land use and have a profound impact on land. Landslides brought on by Hurricane Mitch in Honduras, for example, caused sedimentation 600 times greater than the normal annual average for the region and enormous loss of life (Perotto-Bladiviezo and others 2004).

Human-induced climate change is likely to increase the incidence of extreme events by changing rainfall and temperature patterns and upsetting existing equilibriums. For example, while average rainfall in some areas may not increase (and may even decrease), its distribution may be affected, with intensive and concentrated periods of rainfall followed by extended drier seasons. Few land-use systems will be able to adjust to the impacts of climate change, and new systems will have to evolve to cope with these disturbed rainfall

box 15.5 Climate change has increased the vulnerability of agriculture on Mt. Kilimanjaro, Tanzania

One of Africa's most established and oldest irrigation systems lies on Mt. Kilimanjaro. Massively increased agricultural intensification has meant that this system cannot meet irrigation demand. Up to 85% of water, however, is being lost. Canals are poorly constructed and leaky, while plots are inadequately prepared to receive the irrigation water. In the past, such inefficiency was masked by an abundance of water and relatively low agricultural intensity. Although current rainfall on the mountain's slopes remains good (1,200–2,000 millimeters a year), competition among farmers has reduced the relative amount of water per farmer. The importance of melt-water from the mountain's famous ice cap has increased proportionally. The ice cap, however, is close to disappearing as average temperatures have risen, threatening centuries-old land-use systems and markedly increasing human vulnerability in the area.

Source: IUCN 2003.

patterns. Developed countries account for most greenhouse gas and other global warming emissions. Although developing countries contribute very little to global greenhouse gas emissions, it is these very vulnerable countries that will feel the brunt of the impact from climate change (box 15.5). Where land degradation is already a problem, this vulnerability is substantially increased.

Poverty and livelihoods

> By causing land productivity to decline, land degradation has implications for food security

By causing land productivity to decline, land degradation has implications for food security. While the relationship between land degradation and food insecurity is difficult to demonstrate, there is no question that the poor are clustered on the most degraded and fragile land. Such land is also often very vulnerable to climate factors such as drought or flooding. The kinds of risks that these farmers face in tilling such land cannot typically be mitigated by investments, because farmers are too poor to make the necessary investments. Risk aversion is costly, and to reduce the time over which these costs are incurred, small-scale farmers may choose to intensify their land-use practices at the expense of land sustainability, contributing further to land degradation.

As smallholders struggle against these odds, land productivity declines, having implications for health through malnutrition and exposure to agricultural chemicals in an effort to reduce risk, and increasing the amount of labor required per unit of agricultural output.

The main elements and drivers of land degradation and their impacts pervade the societies that rely on land, rendering them more vulnerable and potentially destroying them. This section considers two key areas of concern with respect to the human impact of land degradation: health and labor.

Impacts of land degradation on human health

An estimated 1.7 billion rural people live on marginal land (Scherr 1999) in areas with noticeable land and water degradation. Areas with the greatest potential for land and water degradation—areas with highly weathered soils, steep slopes, inadequate or excess rainfall, and high temperatures—appear to correspond closely with areas of the highest rural poverty and malnutrition (table 15.1). There are strong indications that the consequences

table **15.1** **Relationship between rural poor and marginal land in developing country regions**

Region	Rural poor on favored lands (millions)	Rural poor on marginal lands: Number (millions)	Rural poor on marginal lands: Share of total (percent)
Sub-Saharan Africa	65	175	73
Asia	219	374	63
Central and South Africa	24	47	66
West Asia and North Africa	11	35	76
Total	319	613	66

Source: Scherr 1999.

of land degradation for food security at the household level already significantly affect many people (Bridges and others 2001). Land degradation implies a reduction in land productivity and the need for purchased inputs to maintain productivity.

The negative impact of soil degradation on productivity has a more profound effect on food security and hunger in areas cultivated primarily by smallholders than in areas where farmers have larger landholdings. In Honduras, for example, much steep land is cultivated mainly by smallholder farmers. Policies that resulted in inequitable land distribution and an increase in the absolute number of farmers have resulted in 10% of producers holding 90% of land designated as agricultural. Land shortages and external pressures for land make subsistence agriculture all the more difficult. By 1989 the area in southern Honduras cultivated with maize had declined to 49% of its 1952 level, while per capita production fell to 28% of its previous level. The area cultivated with beans fell to 15% of its 1952 level and to 5% of its per capita production (Stonich 1993, p. 73). Conroy, Murray, and Rosset (1996, p. 30) report that throughout Central America in the 1980s, per capita maize production fell 14% and bean production fell 25%.

Areas with the greatest potential for land and water degradation appear to correspond closely with areas of the highest rural poverty and malnutrition

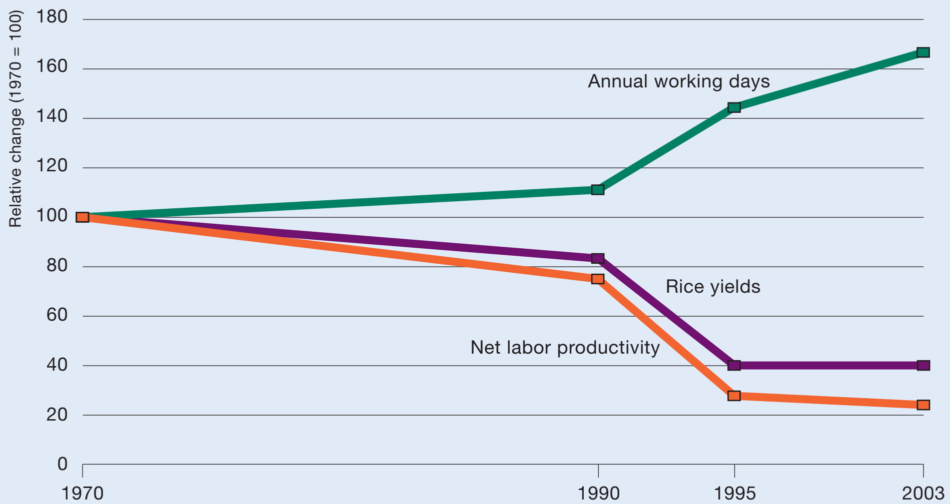
In Sub-Saharan Africa the burden of disease is especially severe. Malaria and HIV/AIDS are more prevalent in Africa than on other continents. Inadequate nutrition and inadequate healthcare render these diseases all the more crippling. There is also a negative feedback for land degradation in that the debilitating effect of illness on people of all ages has a direct impact on their capacity to look after the land.

These patterns are characteristic of much of the developing world. An additional concern for the health of smallholder farmers is the impact of agrochemicals, particularly pesticides, which can be severe. In the 1940s farmers in the lowland areas of Mexico's Yaqui Valley adopted irrigation agriculture that relied heavily on chemical fertilizers and pesticides (Guillette and others 1998). In studies in 1990 high levels of multiple pesticides were found in the umbilical cord blood of newborns and in breast milk, with alarming implications for the physical and mental development of the area's children.

Impacts of land degradation on labor

As land degradation worsens, the time needed to produce the same or better harvests increases, along with the need to increase inputs. Land degradation, therefore, has serious cost implications in terms of time, labor, and agricultural inputs. In a resettled village of northern Lao PDR yields have plummeted while associated annual work time has soared (Pelletreau 2004). Under a slash and burn agricultural system with decreased fallow (from approximately nine to three years), lengthened cropping period (figure 15.6; Lestrelin, Giordano, and Keohavong 2005), and no use of fertilizers and herbicides, the yield decline is associated with fertility exhaustion and soil erosion. As land degrades, new opportunities open up for hardier types of vegetation—such as weeds. In the Laotian case labor increases were due primarily to weed invasion, with the number of hand weeding operations increasing from one to four (de Rouw, Baranger, and Soulilad 2002). Yields have declined 75% over the last 30 years.

As described above, land degradation has profound affects on hydrology (both through the soil and at catchment scales) and on water quality. As permanent water courses figure **15.6** **As land degradation worsened in a northern village in Lao PDR, annual working days rose, while yields and labor productivity plunged**



Source: Adapted from Pelletreau 2004.

become seasonal, wells dry up or water quality declines, and access to adequate water resources for household and livestock needs declines. The time and effort expended in obtaining water supplies therefore increasese. In this way, too, land degradation contributes to increased labor costs.

As is the case with negative health impacts, labor increases have severe implications for livelihood success. The success of rural livelihoods has always been dependent on diversity as well as agricultural productivity. Farming communities might also fish, collect forest products, herd, engage in petty commerce, and so on. As land degrades, however, the need for diverse income sources is accentuated, forcing many rural people to search for alternative income streams from urban areas, plantations, and other sources. And as the most productive resources become increasingly scarce, competition for them can reach the point where violence erupts among different users. Whatever the cause, the impacts of land degradation on those who rely most heavily on ecological services and natural capital are severe, widespread, and reach upwards and outwards to national and regional scales (MEA 2005).

Response options

Many land degradation problems arise because of the simplification of agroecosystem structures. To increase yields, farmers must be able to control weeds, wild herbivores, and pathogens and make nutrients accessible to their crops. All types of agricultural systems have negative environmental impacts of varying degrees over time, with some systems yielding no detectable land degradation for long periods and others developing symptoms very quickly. As a general rule, the greater the effort to control ecological processes, the more rapidly is degradation likely to occur. Typically, if manipulation is extensive, degradation can be compensated for through the addition of substantial agricultural inputs far beyond the reach of most smallholder agriculturalists. The sensible solution, therefore, is to advocate agricultural systems with complex structures and a minimal ecological footprint. This section considers various options for doing this:

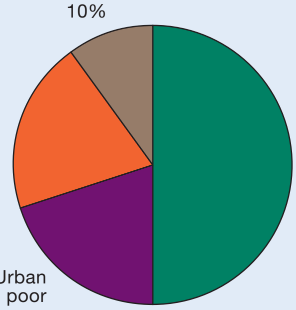
- *Focusing on smallholder agriculture.* With smallholder agriculture likely to persist for some time to come in developing countries, development and conservation investments should treat the smallholder as the most promising unit around which land and water management can occur.
- *Applying integrated solutions for sustainable land management.* Multiple and synergistic measures should be attempted to treat land degradation at the landscape level. These need to focus on resource-conserving strategies and technologies supported by enabling policy and institutional environments to achieve sustainable increases in land and water productivity and reduce vulnerability to climate change.
- *Enhancing the multifunctionality of agricultural landscapes.* When agricultural land use is understood as an integral part of broader landscapes, synergies can be enhanced with other ecosystem functions. Ecoagricultural approaches offer significant benefits. Landscape success stories (so-called bright spots) provide multiple functions through increased carbon sequestration and reduced water pollution.
- *Creating opportunities from high population densities.* Global population increases are unlikely to be curtailed any time soon. Research needs to focus on identifying land-use systems that can tolerate such densities, while policy needs to promote their implementation.

The smallholder unit is the single most promising sector for influencing land- and water-use management to have a discernable, positive impact on rural livelihoods

Focusing on smallholder agriculture

Smallholders carry out 60% of global agriculture, providing 80% of food in developing countries (Cosgove and Rijsberman 2000). Most developing economies are not growing fast, so it is unlikely that alternative or supporting income-earning opportunities will keep pace with population growth. The largest proportion of the developing world's undernourished people are concentrated among smallholder agricultural groups (figure 15.7). Thus, it makes sense to concentrate land and water sector development investments at this level. The importance of such a focus is reflected in several recent strategy papers (see, for example, the 2004 Copenhagen Consensus and Beijing Consensus). While forests, rangelands, and other common property areas are important, the smallholder unit is the single most promising sector for influencing land- and water-use management to have a discernable, positive impact on rural livelihoods. It is the most productive sector of the rural economy in most countries and the most sensitive to land degradation. Land and its use represent vital buffers for poor people in the developing world, shielding them against the vagaries of the delicate economies in which they live. It is important then to consolidate the security that land use represents and to improve its sustainability.

box **15.7** **Smallholder farmers constitute the largest share of the developing world's undernourished, 2004**



Source: FAO 2004.

Applying integrated solutions for sustainable land management

Over the last two decades new thinking has emerged on resource-conserving agriculture (box 15.6; Shaxson 1988; Hudson 1992; Hurni and others 1996; Pretty 1995). It calls for the introduction of participatory methods in decisionmaking and implementation that emphasize training and capacity building and ensure high levels of voluntary engagement by those who should have a stake in what is done. This approach recognizes that indigenous skills and the innovative capacity of smallholders represent a vital localized resource for managing and conserving land (Richards 1985; Warren, Slikkerveer, and Brokensha 1995) and that participatory methods allow these skills and technologies to be tapped.

Photo by William Critchley

Photo 15.2 Mulching can improve productivity and conservation

This new approach aims to provide a basket of options to small-scale farmers, rather than a single technical panacea to the problems of land degradation. It recognizes that production rather than conservation itself is the priority of resource-poor farmers. Thus, in-field practices such as mulching (photo 15.2), composting, cover cropping, mixed cropping, and agroforestry receive emphasis. These can simultaneously improve the soil, reduce its vulnerability to erosion, and improve production, thus achieving the objectives of both productivity and conservation. Furthermore, cross-slope vegetative barriers, which can do double duty as livestock fodder, are increasingly promoted in place of inert structures of earth or stone.

Such structures still have a role to play, however, as part of a package of measures to augment soil depth, reduce off-site sedimentation, and enhance the biological, chemical, and physical health of the soil. There is also a widely acknowledged need to move away from the narrow spatial and temporal confines of blueprint projects to longer term and more responsive programs or processes. The basket of options approach will require changes in attitude by extensionists and decisionmakers, because less standard approaches

box 15.6 | **Resource-conserving agriculture covers a broad range of systems**

The term *resource-conserving agriculture* covers farming systems that aim to conserve natural resources and minimize negative environmental impacts. There are several close similarities in approach. These include plant diversification, plant and animal integration, and an emphasis on soil quality, especially soil organic matter, and on biological solutions to fertility and pest control where possible. A selection of strategies ranging from overall holistic systems to more specific situation-oriented forms, typically used in conjunction, are as follows:

- Organic farming, where artificial additions to the farming system (inorganic fertilizers and agrochemicals) are avoided, and the role of nature is emphasized.
- Conservation agriculture, which combines noninversion tillage (minimum or zero tillage in place of plowing) with mulching or cover cropping and crop rotation to improve soil quality and reduce erosion and costs.
- Ecoagriculture, which emphasizes managing agricultural landscapes to enhance production while conserving or restoring ecosystem services and biodiversity.
- Agroforestry, which incorporates trees into agricultural systems and stresses the multifunctional value of trees within those systems (see photo).
- Integrated pest management, which uses ecosystem resilience and diversity for pest, disease, and weed control and seeks to use pesticides only when other options are ineffective.
- Integrated nutrient management, which seeks both to balance the need to fix nitrogen within farm systems with the need to import inorganic and organic sources of nutrients and to reduce nutrient losses through erosion control.
- Integrated livestock systems, especially those that incorporate stallfed dairy cattle, small stock, and poultry, which raise overall productivity, diversify production, use crop by-products, and produce manure.
- Aquaculture, which brings fish, shrimp, and other aquatic resources into farm systems—irrigated rice fields and fishponds—and increases protein production.
- Water harvesting in dryland areas, which maximizes the use of scarce rainfall by capturing runoff (and sediments) for productive purposes.

Photo by William Critchley

Agroforestry system in Kenya

call for more flexibility and acceptance of indigenous knowledge. In addition, empowering farmers may mean disempowering others.

Better monitoring and evaluation of land degradation underpinning a broader knowledge base are crucial to support these efforts (a forerunner is the World Overview of Conservation Approaches and Technologies, WOCAT; see www.wocat.net).

New policy emphases on institutions and gender. Much policy that relates to land use and degradation suffers from a lack of integration. For example, policies to tackle one aspect of land use, such as conservation, may fail to anticipate spinoff consequences, such as resettlement, that suddenly increase local population density and result in land degradation. Policy needs to anticipate indirect consequences. Of particular concern, here, are impacts on institutions and gender.

Institutions are regular patterns of behavior between individuals and groups in a society that serve a collective purpose (Leach, Mearns, and Scoones 1997; see chapter 5 on policies and institutions). Identifying and fostering responsive, local-level institutions as the basis for decisionmaking and governing land and its use are a powerful response option that managers, administrators, and policymakers can exploit (Ayre and Callway 2005). Achieving an understanding of local-level institutions and how they can be harnessed to tackle land degradation is central to developing effective responses at the community level. Recognizing the role of women in local institutions may be particularly crucial for achieving successful resource management (box 15.7). As already noted, nearly all the food in developing countries is produced by women, and evidence presented here and previously suggests that women can manage resources equitably (Alderman and others 2003).

Bright spots—local contexts, institutions, and policy environments. Agricultural production must increase to feed growing populations. With increasing restrictions on land and water availability, this goal will have to be achieved through intensification—by increasing the productivity of land and water. This may require focusing on the most resilient lands and accepting that certain areas are too fragile for sustainable farming or herding. To make such initiatives sustainable in the long term, resource degradation needs to be mitigated or prevented, while the ecosystem services of the land need to be increased (McNeely and Scherr 2003).

There is ample evidence that it is possible to intensify agriculture in ways that are sustainable and that balance the various goods and services we expect from agricultural landscapes. Success stories have received considerable attention in recent years.[1] One study compiled evidence from bright spots (Noble and others 2006) in 438 recent cases from 57 countries across 11 million farms covering 32 million hectares (table 15.2). Productivity increases were demonstrated across a wide range of farming systems. One of the most

box **15.7** **Women's leadership of community forestry leads to improved watershed management**

Nepalese forest policy encourages women to take a leading role in forest management, and there are several examples of forests being effectively managed by women. The first women's forest user committee was formed in 1990. By 2002, 442 of 10,901 forest user committees in 53 districts were women's groups. The women's groups range from 11 members to 843 members.

Women appear to take a broader view of managing forest resources than do men. The women's committees apply the concept of ecological sustainability to the management of community forests, taking into account the multiple needs that communities have for forest resources. For example, women instituted the protection of Ahal, ponds in which domestic buffalo swim downstream of the forest. They established nurseries to promote agroforestry in forests and villages to increase wood availability. In contrast, male-dominated committees tended to protect forests simply by restricting access, without taking into account the needs of the community for fuel wood and fodder. This often led to continued exploitation and degradation of forest margins.

Source: Pranita Bhushan, Nepal Water Conservation Foundation, Nepal, personal communication.

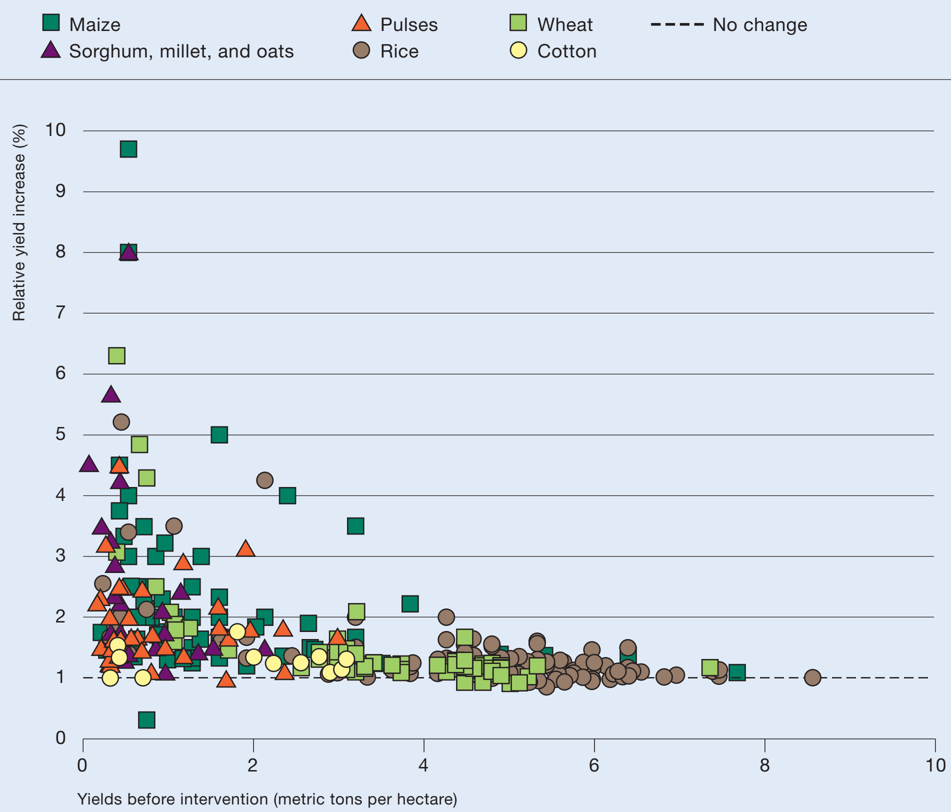
table 15.2 Summary of global adoption and impact of sustainable agricultural technologies and practices on 438 projects in 57 countries			
Food and Agriculture Organization farm system category[a]	Number of farmers	Number of hectares under sustainable agriculture	Average increase in crop yields[b] (percent)
Smallholder irrigated	172,389	357,296	169.8 (±197.2)
Wetland rice	7,226,414	4,986,284	21.9 (±32.3)
Smallholder rainfed humid	1,708,278	1,122,840	129.3 (±167.3)
Smallholder rainfed highland	387,265	702,313	112.3 (±122.3)
Smallholder rainfed dry/cold	579,413	719,820	98.6 (±95.3)
Dualistic mixed[c]	466,292	23,515,847	55.3 (±32.4)
Coastal artisanal	220,000	160,000	62.0 (±28.3)
Urban-based and kitchen garden	206,492	35,952	158.8 (±98.6)
Total	10,966,543	31,600,351	
Weighted mean[d]			156.4

a. Based on the farming systems classification of Dixon, Gulliver, and Gibbon (2001) .
b. Increase from levels before initiation of the project.
c. Mixed large commercial and smallholder farming systems, mainly from southern Latin America.
d. Based on the area occupied by each farming system.
Source: Noble and others 2006.

important features of these documented success cases is that they have developed within local contexts and associated market, institutional, and policy environments.

The cases represent a wide variety of farming systems and innovations. They all incorporate resource-conserving technologies (see box 15.6) assisted in various ways, such as extension advice directed at individuals or extension contact with community-based watershed management institutions. Support has come from both nongovernmental organizations and government services. These cases and those from other sources provide compelling evidence that improvement is possible, even though global degradation trends remain a major concern.

These cases also show that it is possible to preserve and restore resources while simultaneously boosting productivity. This means that it is not necessary to trade off resource conservation to achieve increased production. Significantly, the area of greatest impact was found in smallholder agricultural systems (see table 15.2), and the greatest relative yield increases were achieved where original yield levels were very low, less than 1.5 metric tons per hectare (figure 15.8). Thus, the win-win potential is greatest in the "one ton" agricultural systems that dominate rainfed farming in Sub-Saharan Africa. In these very low-yielding and degraded systems adopting resource-conserving agricultural methods of the sort described in box 15.6 often means an increase in inputs of organic and inorganic fertilizers, water, and sometimes labor. Thus, the lag time in productivity stabilization or gains that is often experienced when transitioning from high input-intensive systems to organic or lower input systems is not necessarily a factor. The largest areas of land adopting resource-conserving agriculture, however, were primarily in Latin American mixed large-scale commercial and smallholder farming systems that had adopted conservation figure **15.8** **Changes to crop yields with agricultural sustainability technologies and practices were greatest where initial yields were smallest (360 crop yield changes in 198 projects)**



Source: Pretty and others 2006.

tillage. Priming factors in these successful cases included investment, secure land tenure, appropriate integrated land and water technologies, aspirations for change among local populations, and effective leadership.

An important feature of many of the bright spots examples is that they are embedded in traditional agricultural systems. These traditions have evolved—often through local innovation—within very specific localized environmental conditions and therefore yield important clues to the characteristics of appropriate land use for these environments. Thus, bright spots often result from improving on local traditions and knowledge through innovation and adaptation (Critchley, Reij, and Willcocks 1994).

Increasing soil and water productivity. Many soil conservation initiatives have focused narrowly on capturing eroded soil without integrating productivity improvements (box 15.8) or addressing the causes of degradation. Accelerated runoff and erosion are essentially

box 15.8 | **The relationship between soil loss and onsite productivity**

It is often assumed that soil erosion is linearly related to reduced soil fertility and hence to a reduction in productivity. Thus soil productivity declines are often equated with the quantity of soil particles lost through erosion. As a result, many soil conservation programs simply seek to control soil and water loss, expecting a predictable return.

There is not, however, a clear and linear relationship between soil loss and soil productivity. In Ethiopia, for example, cross-slope soil conservation technologies substantially reduced soil loss compared with control plots over a three- to five-year period. There was, however, no increase in productivity in the short term (Herweg and Ludi 1999). Similar results were obtained with contour hedgerows in Peru (Shaxson and Barber 2003). Nevertheless, Stocking (2003) graphically demonstrate how the negative impact of erosion on yield differs considerably from soil to soil, though the rate of decline is most rapid initially (see figure 15.3). The key is to prevent early degradation, when erosion (especially interrill erosion, which selectively removes nutrient-rich particles) is most damaging to production. The downstream impacts of erosion are much more closely related to the quantity of soil eroded, however, than are the onsite impacts that are discussed here.

consequences of declining soil quality. Improving soil quality by increasing organic matter has the additional benefit of providing significant resilience in systems otherwise vulnerable to extreme climate events and climate variability.

Investing in improved soil management and quality can considerably improve water productivity in both rainfed and irrigated agricultural systems. Soil management practices to improve infiltration and soil water storage (such as zero till) can boost water use efficiency by an estimated 25%–40%, while nutrient management can boost water use efficiency by 15%–25% (Hatfield, Sauer, and Prueger 2001). Water productivity improvement can range from 70% to 100% in rainfed systems and from 15% to 30% in irrigated systems using resource-conserving agricultural techniques that enhance soil fertility and reduce water evaporation through conservation tillage (table 15.3; Pretty and others 2006).

Rehabilitating degraded soils can improve water productivity even more. Some sandy soils in northeastern Thailand display severe nutrient and carbon depletion after 40 or more years of agricultural production. Crops often fail because nutrients and water are unavailable. Annual precipitation of about 1,100 millimeters is sufficient for rainfed farming, but this amount of freshwater is often consumed with zero productivity, when crops fail. Fertilizers or supplemental irrigation does not stabilize yields because of the soil's very low capacity to retain water and nutrients. The application of clay materials can significantly improve the soil's nutrient- and water-holding capacities (Noble and Suzuki 2005), dramatically increase the system's water productivity, and restore yields.

Water productivity can be improved by implementing better adapted cropping systems, particularly in semiarid environments (Hatfield, Sauer, and Prueger 2001). Examples such as the documented bright spots (Noble and others 2006) suggest that improved land management is one of the most promising ways of increasing water productivity in low-yielding rainfed systems (Falkenmark and Rockström 2004).

table **15.3** **Changes in water productivity from the adoption of sustainable agricultural practices in 144 projects, by crop type (kilogram of produce per cubic meter of water used by evapotranspiration)**

Crop	Before intervention	After intervention	Gain	Increase (percent)
Irrigated agriculture				
Rice (18 projects)	1.03 (±0.52)	1.19 (±0.49)	0.16 (±0.16)	15.5
Cotton (8 projects)	0.17 (±0.10)	0.22 (±0.13)	0.05 (±0.05)	29.4
Rainfed agriculture				
Cereals (80 projects)	0.47 (±0.51)	0.80 (±0.81)	0.33 (±0.45)	70.2
Legumes (19 projects)	0.43 (±0.29)	0.87 (±0.68)	0.44 (±0.47)	102.3
Roots and tubers (14 projects)	2.79 (±2.72)	5.79 (±4.04)	3.00 (±2.43)	107.5

Note: Numbers in parentheses are standard errors.

Source: Pretty and others 2006.

Enhancing the multifunctionality of agricultural landscapes

Enhancing the multifunctionality of agricultural landscapes means increasing the types of ecosystem services derived or supported by the landscape, while maintaining agricultural production as a primary function. The dominant trend in food production systems has been to radically simplify landscapes, greatly increasing the single service of food production (often a single commodity) while reducing other provisioning and supporting services (see chapter 6 on ecosystems). When this simplification is accompanied by detrimental land-use practices, the result is degradation. In initially high productive-potential areas, degradation may be slow, but on low quality soils or otherwise fragile lands even modest levels of simplification and use can be degrading. Awareness of the full range of services of improved land-use systems is growing (MEA 2005), and efforts to quantify and value these services are important for reversing these trends.

Multifunctionality can be enhanced at both farm and landscape scales. On-farm diversification, as in many resource-conserving farming systems (see box 15.6), is one way to diversify livelihoods, reduce vulnerability, and achieve other ecosystem benefits, such as carbon sequestration (Pretty and others 2006). Integrated pest management systems use specialized on-farm niches to increase overall landscape functionality. They use the borders of fields for plants that attract pollinators and other beneficial insects, for example, thus providing more sustainable pest control, with the added benefit that these often perennial vegetation strips provide habitat for small animals (Earles and Williams 2005).

Landscape approaches that go beyond farm scale are also necessary because land degradation has causes and impacts beyond the location where it is observed. Land degradation often arises because of the failure to integrate the agroecological system into the broader landscape in which it is located. Vital ecosystem functions, particularly related to water cycling, cannot be maintained without a larger scale approach within an ecosystem context. Landscape approaches take into account the ecology and function of the landscape's components and make strategic use of their potential, integrating agriculture into an ecosystematic whole (Ryszkowski and Jankowiak 2002).

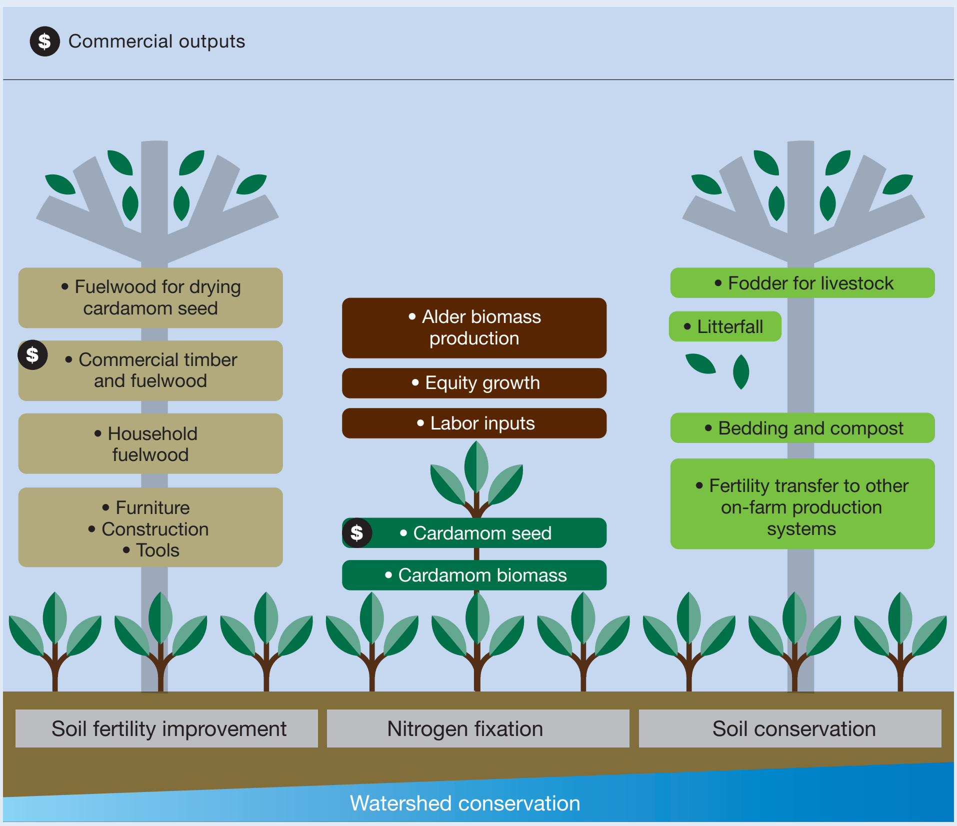
At the landscape level there are several ways to increase multifunctionality with overall benefit. One way is to actively manage nonfarmed land in and around farmed land. This includes waste land and riparian zones. In a system widespread in the Eastern Himalayas

box **15.9** **Meeting diverse needs through alder-cardamom agroforestry in riparian zones**

In the Eastern Himalayas (Sikkim and Assam in India and in Nepal) steep slopes, low soil fertility, tectonic activity, and intense precipitation cause erosion and slumping. Together with increasing population pressures, this makes land management difficult. One response was the strategic planting of an alder-cardamom agroforestry system in riparian zones (see figure), which satisfied a diversity of farmers' needs while protecting the land from severe biophysical pressures (Zomer and Menke 1993).

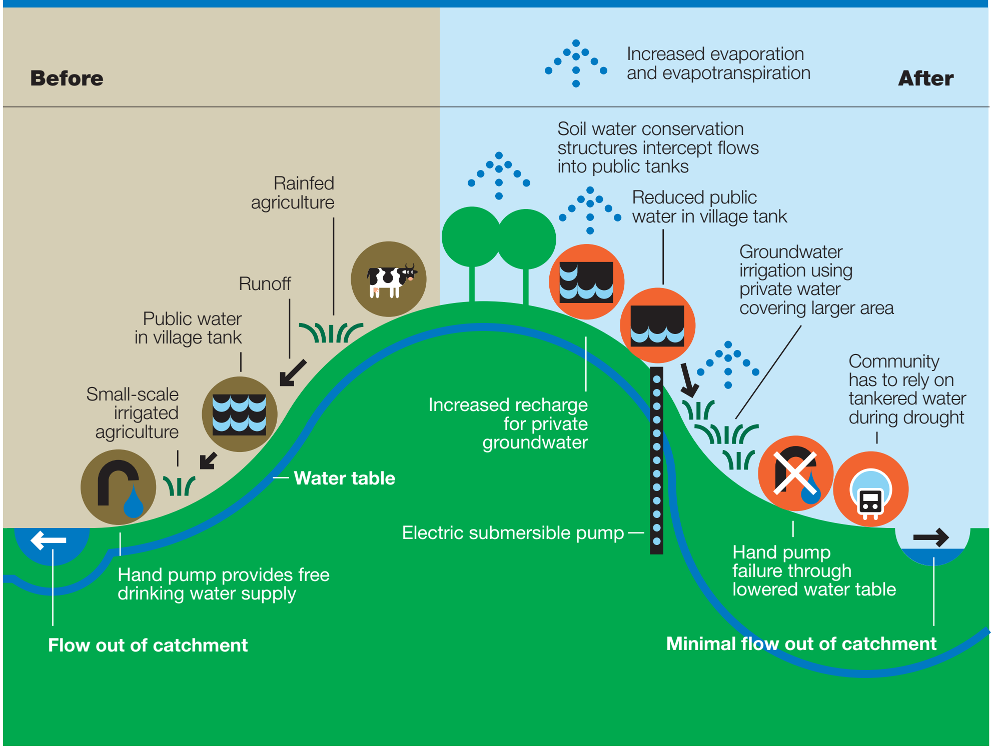
Riparian buffers trap sediment and reduce bank erosion, providing significant water quality benefits. This type of conservation-production system increases the provision of ecosystem goods and services at the landscape scale, which cannot always be achieved when management targets only lands under annual cropping systems.

Alder-cardamom agroforestry system



Source: Adapted from Zomer and Menke 1993.

figure **15.9** **Too many catchment interventions can alter catchment flows**



riparian zones become productive parts of the landscape, protecting steep hillsides and river banks from accelerated erosion (box 15.9). Another way is to make greater use of perennials in the farm landscape, creating land-use mosaics, interspersing perennials and small patches of annuals or high-disturbance systems. A mosaic of perennials usually provides more stable plant cover, protecting the soil and increasing infiltration, thus mitigating or reversing some of the negative effects described above. There are often many opportunities to substitute perennials for current annuals (especially to produce livestock feed and oils), and they can also provide new income-earning potential. These approaches may be the only option for sustainable production on degradation-prone lands.

It should be noted, however, that using more perennials will also typically boost local water consumption through increased evapotranspiration, reducing water that might otherwise be available for alternative uses. In semiarid areas, for example, the understanding is growing of the potential for "excessive" implementation of catchment interventions involving irrigation, forestry, and soil water conservation measures to alter catchment flows and the availability of "private" and "public" water, thus becoming a governance and water rights issue (figure 15.9; Calder 2005). The magnitude of such water-use reallocation effects will vary across ecosystems and climate zones (see chapter 16 on river basins) and will also depend on such factors as how much locally used water was previously lost through unproductive evaporation, changes in groundwater recharge, and any impact on local precipitation patterns. This is an area that requires research attention.

Creating opportunities from high population densities

Despite continuing rural-urban migration, it is unlikely that rural populations in developing countries have peaked. National policies cannot afford to focus on controlling population growth alone but must also emphasize research on land-use systems that can accommodate high population densities.

Small-scale farmers in developing countries facing the constraint of high population pressure and known to be innovators should be acknowledged as allies in developing land husbandry systems appropriate under these conditions (Tiffen, Mortimore, and Gichuki 1994). Appropriate interventions need to be stimulated by creating enabling sociopolitical environments. Where political contexts favor secure access to land, and adequate marketing opportunities for produce exist, land users are more willing to develop and implement land husbandry innovations. A review of 70 empirical studies on farming on tropical hillsides found that in many places population growth, especially at higher population densities, led to extensive land-improving investments and conservation management (Templeton and Scherr 1999).

Where political contexts favor secure access to land, and adequate marketing opportunities for produce exist, land users are more willing to develop and implement land husbandry innovations

Conclusion

This chapter has detailed the global extent of land degradation, particularly as viewed from the perspective of livelihoods in developing countries. It makes clear that considerably more research is needed—particularly at water catchment scales—to better understand the multiple drivers underpinning land degradation and the ways in which land users respond to these drivers. It has focused on the sociopolitical and economic contexts within which land degradation occurs to reveal the drivers that cause it and the solution: sociopolitical and economic environments that foster innovative responses to mitigate and prevent land degradation and that are often resource conserving. In addition, the local-level context in which land use occurs reveals important dynamics between different actors at this scale. This includes power relationships between men and women and the importance of tenure—the guarantee of access to resource bases—as a pivotal component in the way land is used and managed (photo 15.3).


Photo by William Critchley

Photo 15.3 Gender relations affect land use

The solutions proposed here call for a policy focus at the small scale capable of providing latitude and encouragement for the development and evolution of local strategies and institutions able to prevent and mitigate land degradation. In addition, the chapter calls for policy and local-level interventions that can stimulate resource-conserving agriculture that improves land and water productivity, relies less on artificial inputs and more on ecosystem services, and works with ecosystem sustainability and contributes to it in the long term. In addition, the chapter calls for an understanding of land use at the landscape level, managing these as a suite of potential activities with ecosystems in common.

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Note

1. Groups with projects cataloguing and detailing success stories include the Centre for Development and Environment, Berne; Centre for Environment and Society, University of Essex; Ecoagriculture Partners; Food and Agriculture Organization Land and Water Development Division; Food and Agriculture Organization/Land and Water Development Division Gateway Project; Centre for International Cooperation, Vrije Universiteit Amsterdam; Institute for Regional Community Development; Sustainability Institute, Stockholm Environment Institute; and the World Overview of Conservation Approaches and Technologies, Berne. See Bridges and others (2001); McNeely and Scherr (2003); and WOCAT (2006).

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