PART I

Sustainable Land Management: Challenges and Opportunities

CHAPTER 1

Overview

Increased investment to promote agricultural growth and poverty reduction is a key objective of the World Bank's (2003) rural strategy, *Reaching the Rural Poor.* A major component of the strategy outlines the priorities and the approaches that the public sector, private sector, and civil society can use to enhance productivity and competitiveness of the agricultural sector in ways that reduce rural poverty and sustain the natural resource base. The pathways and possible actions involve participation by rural communities, science and technology, knowledge generation and further learning, capacity enhancement, and institution building.

The strategy commits the World Bank to five core areas of rural development:

- Foster an enabling environment for broad-based and sustainable rural growth.
- Promote agricultural productivity and competitiveness.
- Encourage nonfarm economic growth.
- Improve social well-being, manage and mitigate risk, and reduce vulnerability.
- Enhance sustainability of natural resource management.

Underlying all of the investments and actions is pro-poor agricultural growth, with the specific aim of helping client countries reach the Millennium Development Goals—especially the goal of halving poverty and hunger by 2015.

While the new rural strategy was being developed, the need to better articulate good practice in agricultural policies and investments became clear. To support the rural strategy, the Agriculture and Rural Development Department compiled and launched the *Agriculture Investment Sourcebook* (World Bank 2004) and *Shaping the Future of Water for Agriculture: A Sourcebook for Investment in Agricultural Water Management* (World Bank 2005a). Those two sourcebooks document and highlight a wide range of emerging good practices and innovative approaches to investing in the agricultural and rural sector. Good land management is essential for sustaining the productivity of agriculture, forestry, fisheries, and hydrology (water), and it affects a range of ecosystem services on which the sustainability of agriculture depends. Hence, this sourcebook has been produced to complement the previous sourcebooks. The focus is on land management for enhanced production as well as ecosystem services (box 1.1).

Until recently, increases in agricultural productivity—particularly in industrial regions of the world—have, with the help of both science and subsidy, pushed world agricultural commodity prices down, thereby making it increasingly difficult for marginal land farmers to operate profitably within existing technical and economic parameters (Sachs 2005). In the first few months of 2008, however, a combination of high oil prices, poor crop yields caused by unfavorable weather in major producer countries such as Australia, skyrocketing demand for grains for biofuels (ethanol), and market speculation has pushed commodity prices to all-time highs. This price trend is projected to continue for the foreseeable future and will stimulate rapid

Box 1.1 Ecosystem Services

An *ecosystem* is a dynamic complex of plant, animal, and microorganism communities and the nonliving environment interacting as a functional unit. Examples of ecosystems include natural forests, landscapes with mixed patterns of human use, and ecosystems intensively managed and modified by humans, such as agricultural land and urban areas. *Ecosystem services* are the benefits people obtain from ecosystems. They include the following:

- Provision services such as food, water, timber, and fiber
- Regulated services that affect the climate, floods, disease, waste, and water quality
- Cultural services that provide recreational, aesthetic, and spiritual benefits
- Support services such as soil formation, photosynthesis, and nutrient cycling.

The human species, while buffered against environmental changes by culture and technology, fundamentally depends on the flow of ecosystem services.

Source: http://www.millenniumassessment.org.

expansion or intensification of agricultural land use—or both. Good land management practices will be essential to sustain high productivity without degrading land and the associated natural resource base.

STRUCTURE OF THE SOURCEBOOK AND GUIDE FOR USERS

This sourcebook is intended to be a ready reference for practitioners (including World Bank stakeholders, clients in borrowing countries, and World Bank project leaders) seeking state-of-the-art information about good land management approaches, innovations for investments, and close monitoring for potential scaling up.

This sourcebook is divided into three parts:

- Part I identifies the need and scope for sustainable land management (SLM) and food production in relation to cross-sector issues such as freshwater and forest resources, regional climate and air quality, and interactions with existing and emerging infectious diseases. It introduces the concept of production landscapes and analysis of trade-offs and establishes a framework for linking indicators that provide a measure of the outcomes of SLM. It then categorizes the diversity of land management (that is, farming) systems globally and the strategies for improving household livelihoods in each type of system. For the farming system types, a set of SLM principles and common but important issues for future investments are identified.
- Part II focuses on three major farming system types and presents a range of Investment Notes and Innovative Activity Profiles:
  - *Investment Notes* summarize good practices and lessons learned in specific investment areas. They provide a brief, but technically sound, overview for the nonspecialist. For each Investment Note, the investments have been evaluated in different settings for effectiveness and sustainability, and they have been broadly endorsed by a community of practitioners operating both within and outside the World Bank.
  - *Innovative Activity Profiles* highlight the design of successful or innovative investments. They provide a short description of an activity that is found in the World Bank's portfolio or that of a partner agency and that focuses on potential effectiveness in poverty reduction, empowerment, or sustainability. Activities profiled often have not been sufficiently tested and evaluated in a range of settings to be considered good practice, but they should be closely monitored for potential scaling up.
- Part III provides users of the source book with easy-to-access, Web-based resources relevant for land and natural resource managers. The resources are available in the public domain, and readers can access the Web sites of various international and national agencies.

This sourcebook provides introductions to topics, but not detailed guidelines on how to design and implement investments. The Investment Notes and Innovative Activity Profiles include a list of references and Web resources for readers who seek more in-depth information and examples of practical experience.

This first edition draws on the experiences of various institutional partners that work alongside the World Bank in the agriculture and natural resource management sectors. Major contributors are research and development experts from the Consultative Group on International Agriculture Research centers, together with their national partners from government and nongovernmental agencies. The diverse menu of options for profitably investing in SLM that is presented is still a work in progress. Important gaps still need to be filled, and good practices are constantly evolving as knowledge and experience accumulate. The intention of this sourcebook is to continue to harness the experience of the many World Bank projects in all regions as well as those of partners in other multilateral and bilateral institutions, national organizations, and civil society organizations. The sourcebook will be updated annually.

THE NEED FOR SUSTAINABLE LAND MANAGEMENT

Land-use activities—whether converting natural landscapes for human use or changing management practices on human-dominated lands—have transformed a large proportion of the planet's land surface. By clearing tropical forests, practicing subsistence agriculture, intensifying farmland production, or expanding urban centers, humans are changing the world's landscapes. Although land-use practices vary greatly across the world, their ultimate outcome is generally the same: (a) to produce food and fiber and (b) to acquire natural resources for immediate human needs.

The sections that follow present the rationale for why SLM is a critical cross-sector driver for maintaining production and services from human-dominated landscapes. The challenges identified are also entry points for carefully targeted interventions and represent opportunities for pro-poor investments.

DEFINITION OF SUSTAINABLE LAND MANAGEMENT

Sustainable land management is a knowledge-based procedure that helps integrate land, water, biodiversity, and environmental management (including input and output externalities) to meet rising food and fiber demands while sustaining ecosystem services and livelihoods. SLM is necessary to meet the requirements of a growing population. Improper land management can lead to land degradation and a significant reduction in the productive and service functions (World Bank 2006).

In lay terms, SLM involves these activities:

- Preserving and enhancing the productive capabilities of cropland, forestland, and grazing land (such as upland areas, down-slope areas, flatlands, and bottomlands)
- Sustaining productive forest areas and potentially commercial and noncommercial forest reserves
- Maintaining the integrity of watersheds for water supply and hydropower-generation needs and water conservation zones
- Maintaining the ability of aquifers to serve the needs of farm and other productive activities.

In addition, SLM includes actions to stop and reverse degradation—or at least to mitigate the adverse effects of earlier misuse. Such actions are increasingly important in uplands and watersheds—especially those where pressures from the resident populations are severe and where the destructive consequences of upland degradation are being felt in far more densely populated areas downstream.

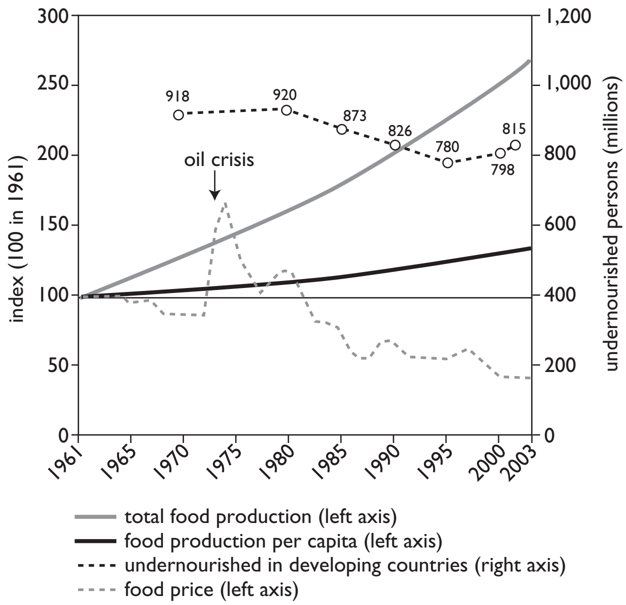
Fortunately, in the past four decades, scientific advances and the application of improved knowledge and technologies by land managers and some farmers have resulted in significant total and per capita food increases, reduced food prices (figure 1.1), and the sparing of new land that otherwise would have been needed to achieve the same level of production (Evenson and Gollin 2003). For example, if yields of the six major crop groups that are cultivated on 80 percent of the total cultivated land area had remained at 1961 levels, an additional 1.4 billion hectares of farmland (more than double the amount of land currently being used) would have been required by 2004 to serve an expanding population. Asia alone would have required an additional 600 million hectares, which represents 25 percent more land area than is suitable for cultivation on that continent. Rather than enjoying surpluses of grains, Asia would now depend heavily on food imports (Cassman and Wood 2005). Nevertheless, those gains have some medium- to long-term costs (figure 1.1).

Until recently, increases in agricultural productivity—particularly in developed regions of the world, where they are facilitated by both science and subsidy—have pushed world agricultural commodity prices down, making it increasingly difficult for marginal land farmers to operate profitably within existing technical and economic parameters. These trends may not be reliable pointers to the future.

In the 21st century, food and fiber production systems will need to meet three major requirements:

1. They must adequately supply safe, nutritious, and sufficient food for the world's growing population.
2. They must significantly reduce rural poverty by sustaining the farming-derived component of rural household incomes.
3. They must reduce and reverse the degradation of natural resources and the ecosystem services essential to sustaining healthy societies and land productivity.

Figure 1.1 Global Food Production, Food Prices, and Undernourishment in Developing Countries, 1961–2003



Source: Millennium Ecosystem Assessment 2005.
Note: The spike in the food price index in 1974 was caused by the oil crisis.

Box 1.2 Historical Perspective on Landscapes, Land Management, and Land Degradation

Concerns about soil and vegetation degradation and the impacts on land and water productivity are not new. Plato, writing about Attica in the fourth century BC, lamented:

> There are remaining only the bones of the wasted body, as they may be called, as in the case of small islands, all the richer and softer parts of the soil having fallen away, and the mere skeleton of the land being left. But in the primitive state of the country, its mountains were high hills covered with soil, and the plains, as they are termed by us, of Phelleus were full of rich earth, and there was abundance of wood in the mountains. Of this last the traces still remain, for although some of the mountains now only afford sustenance to bees, not so very long ago there were still to be seen roofs of timber cut from trees growing there, which were of a size sufficient to cover the largest houses; and there were many other high trees, cultivated by man and bearing abundance of food for cattle. Moreover, the land reaped the benefit of the annual rainfall, not as now losing the water which flows off the bare earth into the sea, but, having an abundant supply in all places, and receiving it into herself and treasuring it up in the close clay soil, it let off into the hollows the streams which it absorbed from the heights, providing everywhere abundant fountains and rivers, of which there may still be observed sacred memorials in places where fountains once existed; and this proves the truth of what I am saying.

Source: DeFries 2003, citing Plato 2003.

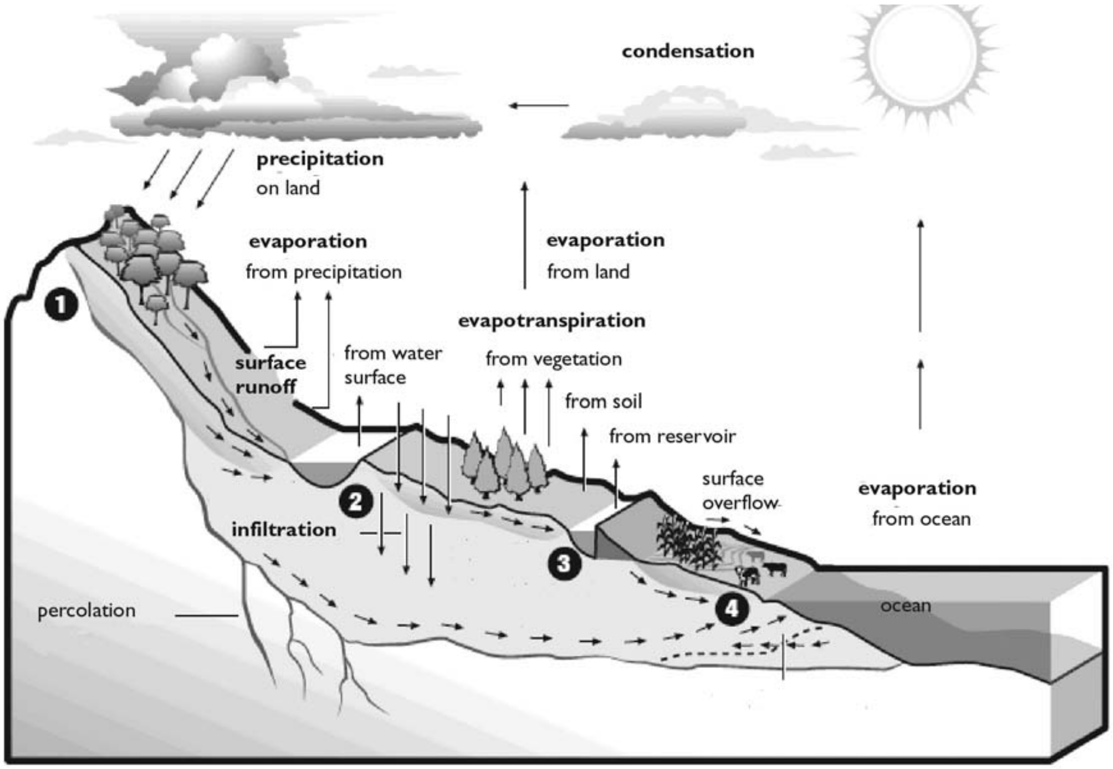
DRIVERS AND IMPACTS OF GLOBAL CHANGE

It is now known that the challenges to sustaining land productivity will need to be resolved in the face of significant but highly unpredictable changes in global climate—a key factor in natural and agro-ecosystem productivity. Other major issues that will influence how land use evolves to meet the challenge of food security include globalization of markets and trade, increasing market orientation of agriculture, significant technological changes, and increasing public concern about the effects of unsustainable natural resource management.

Several decades of research have revealed the environmental impacts of land use throughout the globe. These impacts range from changes in atmospheric composition to the extensive modification of Earth's ecosystems. For example, land-use practices have played a role in changing the global carbon cycle and, possibly, the global climate: Since 1850, roughly 35 percent of anthropogenic carbon dioxide emissions resulted directly from land use. Changes in land cover also affect regional climates by affecting surface energy and water balance (box 1.2).

Humans have also transformed the hydrologic cycle to provide freshwater for irrigation, industry, and domestic consumption. Furthermore, anthropogenic nutrient inputs to the biosphere from fertilizers and atmospheric pollutants now exceed natural sources and have widespread effects on water quality and coastal and freshwater ecosystems. Land use has also caused declines in biodiversity through the loss, modification, and fragmentation of habitats; degradation of soil and water; and overexploitation of native species. Figure 1.2 shows some of the watershed- and landscape-level interactions and potential consequences of

Figure 1.2 Typical Set of Production Activities (Forestry, Crop and Livestock Production, Hydropower, and Coastal Fisheries) Encountered in a Production Landscape



Source: World Bank 2006.
Note: The land management interventions depicted at various points in the landscape all have an impact on surface and subsurface water and nutrient flows and energy balances. Understanding how these interrelated but spatially separated interactions occur is very important for sustainable land management for enhanced productivity and ecosystem functions. ❶ = Forested catchments, ❷ = dams and reservoirs, ❸ = irrigation canals, and ❹ = coastal settlements.

individual land management decisions on water uptake and loss to the atmosphere (*evapotranspiration*) and hydrology.

Human activities now appropriate nearly one-third to one-half of global ecosystem production, and as development and population pressures continue to mount, so could the pressures on the biosphere. As a result, the scientific community is increasingly concerned about the condition of global ecosystems and ecosystem services.

Thus, land use presents a dilemma. On one hand, many land-use practices are absolutely essential for humanity because they provide critical natural resources and ecosystem services, such as food, fiber, shelter, and freshwater. On the other hand, some forms of land use are degrading the ecosystems and services on which we depend. A natural question arises: are land-use activities degrading the global environment in ways that may ultimately undermine ecosystem services, human welfare, and long-term sustainability of human societies?

The subsections that follow examine this question and focus on a subset of global ecosystem conditions that are most affected by land use. They also consider the challenge of reducing the negative environmental impacts of land use while maintaining economic and social benefits.

Food Production

Together, croplands and pastures have become one of the largest terrestrial biomes on the planet, rivaling forest cover in extent and occupying approximately 40 percent of the land surface (figure 1.3). Changes in land-use practices have enabled world grain harvests to double in the past four decades, so they now exceed 2 billion tons per year. Some of this increase can be attributed to a 12 percent increase in world cropland area, but most of these production gains resulted from “Green Revolution” technologies, which include (a) high-yielding cultivars, (b) chemical fertilizers and pesticides, and (c) mechanization and irrigation. During the past 40 years, global fertilizer use has increased about 700 percent, and irrigated cropland area has increased approximately 70 percent.

Although modern agriculture has been successful in increasing food production, it has also caused extensive environmental damage. For example, increasing fertilizer use has led to the degradation of water quality in many regions. In addition, some irrigated lands have become heavily salinized, causing the worldwide loss of approximately 1.5 million hectares of arable land per year, along with an estimated US$11 billion in lost production. Up to 40 percent of global croplands may also be experiencing some degree of soil erosion, reduced fertility, or overgrazing.

The loss of native habitats also affects agricultural production by degrading the services of pollinators, especially bees. In short, modern agricultural land-use practices may be trading short-term increases in food production for long-term losses in ecosystem services, which include many that are important to agriculture.

Freshwater Resources

Land use can disrupt the surface water balance and the partitioning of precipitation into evapotranspiration, runoff, and groundwater flow. Surface runoff and river discharge generally increase when natural vegetation (especially forestland) is cleared. For instance, the Tocantins River Basin in Brazil showed a 25 percent increase in river discharge between 1960 and 1995, coincident with expanding agriculture but no major change in precipitation.

Water demands associated with land-use practices, especially irrigation, directly affect freshwater supplies through water withdrawals and diversions. Global water withdrawals now total approximately 3,900 cubic kilometers per year, or about 10 percent of the total global renewable resource. The consumptive use of water (not returned to the watershed) is estimated to be between 1,800 and 2,300 cubic kilometers per year.

Agriculture alone accounts for approximately 75 percent of global consumptive use. As a result, many large rivers—especially in semiarid regions—have greatly reduced flows, and some routinely dry up. In addition, the extraction of groundwater reserves is almost universally unsustainable and has resulted in declining water tables in many regions.

Land use often degrades water quality. Intensive agriculture increases erosion and sediment load and leaches nutrients and agricultural chemicals to groundwater, streams, and rivers. In fact, agriculture has become the largest source of excess nitrogen and phosphorus to waterways and coastal zones. Urbanization also substantially degrades water quality, especially where wastewater treatment is absent. The resulting degradation of inland and coastal waters impairs water supplies, causes oxygen depletion and fish kills, increases blooms of cyanobacteria (including toxic varieties), and contributes to water-borne disease.

Forest Resources

Land-use activities, primarily for agricultural expansion and timber extraction, have caused a net loss of 7 million to 11 million square kilometers of forest in the past 300 years. Highly managed forests, such as timber plantations in North America and oil palm plantations in Southeast Asia, have also replaced many natural forests and now cover 1.9 million square kilometers worldwide. Many land-use practices (such as fuelwood collection, forest grazing, and road expansion) can degrade forest ecosystem conditions—in terms of productivity, biomass, stand structure, and species composition—even without changing forest area. Land use can also degrade forest conditions indirectly by introducing pests and pathogens, changing fire fuel loads, changing patterns and frequency of ignition sources, and changing local meteorological conditions.

Regional Climate and Air Quality

Land conversion can alter regional climates through its effects on net radiation, the division of energy into sensible and latent heat, and the partitioning of precipitation into soil water, evapotranspiration, and runoff. Modeling studies demonstrate that changes in land cover in the tropics affect the climate largely through water-balance changes, but changes in temperate and boreal vegetation influence the climate primarily through changes in the surface radiation balance. Large-scale clearing of tropical forests may create a warmer, drier climate, whereas clearing temperate and boreal forest is generally thought to cool the climate, primarily through increased albedo.

Urban "heat islands" are an extreme case of how land use modifies the regional climate. The reduced vegetation cover, impervious surface area, and morphology of buildings in cityscapes combine to lower evaporative cooling, store heat, and warm the surface air. A recent analysis of climate records in the United States suggests that a major portion of the temperature increase during the past several decades resulted from urbanization and other land-use changes. Changes in land cover have also been implicated in changing the regional climate in China; recent analyses suggest that the daily diurnal temperature range has decreased as a result of urbanization.

Land-use practices also change air quality by altering emissions and changing the atmospheric conditions that affect reaction rates, transportation, and deposition. For example, tropospheric ozone (O_3) is particularly sensitive to changes in vegetation cover and biogenic emissions. Land-use practices often determine dust sources, biomass burning, vehicle emission patterns, and other air pollution sources. Furthermore, the effects of land use on local meteorological conditions, primarily in urban heat islands, also affect air quality: higher urban temperatures generally cause O_3 to increase.

Infectious Diseases

Habitat modification, road and dam construction, irrigation, increased proximity of people and livestock, and concentration or expansion of urban environments all modify the transmission of infectious disease and can lead to outbreaks and emergence episodes. For example, increasing tropical deforestation coincides with an upsurge of malaria and its vectors in Africa, Asia, and Latin America, even after accounting for the effects of changing population density.

Disturbing wildlife habitat is also of particular concern, because approximately 75 percent of human diseases have links to wildlife or domestic animals. Land use has been associated with the emergence of bat-borne Nipah virus in Malaysia, cryptosporidiosis in Europe and North America, and a range of food-borne illnesses globally. In addition, road building in the tropics is linked to increased bushmeat hunting, which may have played a key role in the emergence of human immunodeficiency virus types 1 and 2. Simian foamy virus was recently documented in hunters, confirming this mechanism of cross-species transfer.

The combined effects of land use and extreme climatic events can also have serious impacts, both on direct health outcomes (such as heat mortality, injury, and fatalities) and on ecologically mediated diseases. For example, Hurricane Mitch, which hit Central America in 1998, exhibited these combined effects: 9,600 people perished, widespread water- and vector-borne diseases ensued, and 1 million people were left homeless. Areas with extensive deforestation and settlements on degraded hillsides or floodplains suffered the greatest morbidity and mortality.

PRODUCTION LANDSCAPES: THE CONTEXT FOR LAND MANAGEMENT

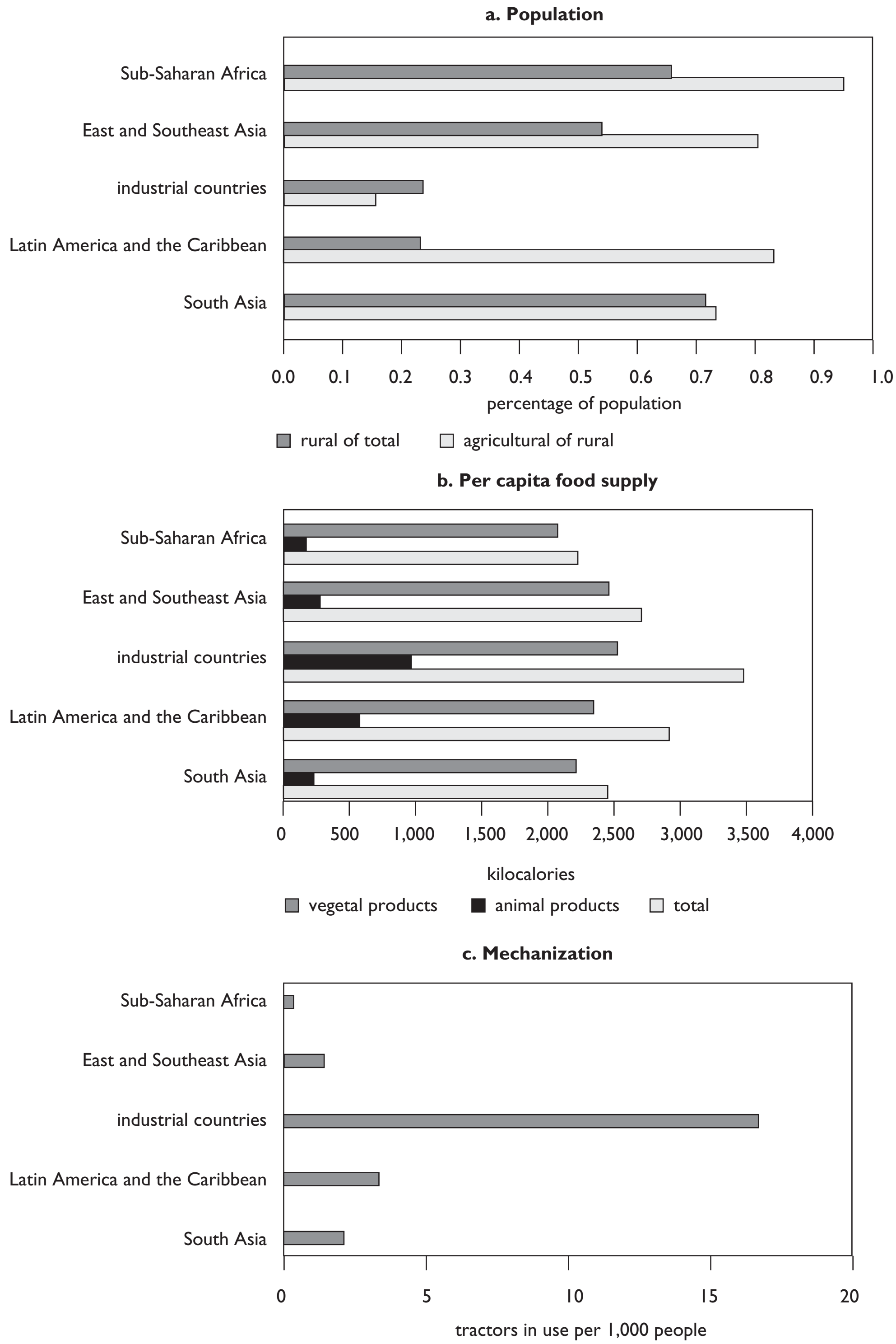
When one travels on an airplane, the view from the window reveals landscapes below with mountain ranges, forests, grasslands, coastlines, and deserts. As human civilization evolved, people planted crops, reared animals, developed complex irrigation schemes, built cities, and devised technologies to make life more comfortable and less vulnerable to droughts, floods, and other potentially damaging climatic events. The outcomes of this human occupation are transformed landscapes over 40 percent of the Earth's ice-free land surface. Only places that are extremely cold, extremely hot, very mountainous, or as yet inaccessible remain free from human use (figure 1.3).

Landscapes also reveal how people obtain their food and pursue their livelihoods. In the industrial world of North America and Western Europe, a majority of people live in urban areas (77 percent in 2003) and obtain food transported from land devoted to high-yield agriculture. Diets are relatively high in animal products. Agricultural production is highly mechanized, with only 15 percent of people living in rural areas engaged in farming or ranching. The pattern is markedly different in parts of the world that are still in agrarian stages of development (figure 1.3).

Although overall global food production has increased 168 percent over approximately the past 40 years and is ample to feed all 6.5 billion people on the planet today, 13 percent of the world's people still suffered from malnutrition between 2000 and 2002 because they were too poor to purchase adequate food. The imprint of this paradox is seen throughout the rural landscape of the developing world in crops grown on infertile soils and steep slopes, mosaics of shifting cultivation, forests scavenged for fuelwood, and seasonal migrations pursuing fodder for livestock. Most people in the developing world live in rural areas, with South Asia having the highest percentage at more than 70 percent (Latin America and the Caribbean is the most urbanized developing region.) Of the rural population throughout all developing regions, the vast majority is engaged in agriculture. These rural farmers grow low-yield crops for their own households and local markets. Diets also contrast with those in the industrial world, with consumption of animal products far less than half that in industrial societies and per capita caloric intake at 65 to 80 percent.

Poverty, agriculture, and land use make a complex and challenging system with many flaws and interacting elements. Poor farmers do not want to be poor, and few choose actively to damage their environments. The reason so many are living on the edge of survival is that too many of their traditional approaches to agricultural production are breaking down. Economic growth has been insufficient to offer alternative means of employment for the rural poor. Profits from farming at low levels of productivity have been too small to allow farmers to reinvest in their farms and maintain productivity at acceptable levels (Eicher and Staatz

Figure 1.3 World Comparisons of Food Production and Consumption 2003



Source: Food and Agriculture Organization statistical databases (FAOSTAT), http://www.faostat.fao.org.
Note: In panel a, the percentage of total population living in rural areas is highest in South Asia and lowest in industrial countries, while agricultural populations (defined as all persons depending for their livelihood on agriculture, hunting, fishing, or forestry) constitute more than 70 percent of the rural population in all developing regions but only 15 percent in industrial countries. In panel b, per capita food supply per day and proportion of total in animal products is highest in industrial countries. In panel c, food production is more mechanized in industrial countries, as illustrated by the number of tractors in use.

1990). Meanwhile, continual increases in population have depleted both the available resource base and social entitlements that hitherto provided a state of equilibrium in rural areas of Africa (Lele 1989).

Those who are most in need of new livelihood options are the least able to pay for them. Furthermore, the advice that they receive on the choices open to them is disgraceful—what the farmer needs is reliability and consistency of performance. A single mother hoping to harvest a metric ton of rice on a hectare of depleted upland soil can ill afford to lose 100 kilograms of her harvest to a crop pest or disease in a single season, even if, under some conditions (which she may not be able to achieve), she can potentially get a higher yield from a new variety. She needs to move to a higher level of productivity but cannot afford the means to lift herself there. Although group savings and credit schemes (such as savings and credit cooperative societies, household income security associations, and self-help groups) can help poor families to access inputs to get out of the poverty spiral, the effectiveness of such interventions is badly blunted when the inputs themselves are inadequately tailored to the needs of the poor. SLM practices are often complex, are difficult to implement, and have payoffs that may be beyond the horizon of the poor. But as the cases in this sourcebook will show, those constraints do not mean that SLM practices are impractical or impossible for the poor to adopt.

Much of the debate on poverty revolves around the low prices that farmers get for their produce. Remember, though, that the first priority for the rural poor is to grow their own food. Many of the rural poor do not even produce enough to feed themselves all year round, so they buy food when supplies are short and prices are high. Poor people do not need expensive food. Thus, an evident priority in the struggle against poverty is to bring food prices down. The costs of many of the improved technologies (such as improved seeds, fertilizer, and livestock breeds) needed by smallholders—despite ongoing efforts at market development—will remain high. Low-cost technologies (such as home-produced seed and household composts) often have a substantial cost in terms of labor—which is also a scarce resource in many poor households.

The advice given to many poor farmers regarding the use of essential inputs (both those purchased from outside and those that the farmer may generate from homestead resources, such as manures and home-produced seed) serves actively to discourage their use. In large part, this outcome occurs because of inadequate incorporation of basic economic parameters into recommendations to farmers (Blackie 2006). The information provided frequently overlooks the obvious fact that an expensive input (whether in cash or labor) can be profitable if it is used efficiently. The knowledge the poor seek is how to make best use of the limited amounts that they are able to purchase. So poverty alleviation and food security have to be arranged around low food prices and efficient production methods. With low food prices, the poor can use their limited cash to invest in better housing, education, and health care. With high food prices, they are further trapped in poverty, and the opportunities for livelihood diversification are few.

The human imprint on the landscape emerges from millions of individual decisions in pursuit of food and livelihoods. Through time, as societies evolve from agrarian to industrial and information-based economies, the landscape mirrors accompanying shifts in how people obtain food, what they eat, and where they work. Historical examples in Europe and North America follow a general pattern, and similar patterns are emerging in some developing regions, but with one major caveat: the early stages of agricultural transformation and industrialization in Europe and North America were supported by significant shifts of populations to new lands through colonization and settlement. In today's crowded world, that safety valve is no longer an option.

Instead a "Green Evolution" strategy is needed to help people transform their own landscapes rather than seeking to escape to fresh pastures. Local knowledge (of soils, landscapes, markets, and climate) is linked to the best of national and international expertise in a focused, problem-solving effort. The focus is on quality and results, facilitated through enhanced networking and coordination among the various sector stakeholders and international organizations. The best options are pulled together and then promoted through large-scale initiatives. The poor influence the choice of recommendations, while the private sector contributes toward sector needs such as seed and market systems. In that way, the power of millions of individuals' decisions can be tapped to create a more benign and sustainable human imprint on the landscape. The Green Evolution strategy encourages the efficient and swift transformation of practices leading to SLM by harnessing the best skills in a collaborative, learning-by-doing manner in which all people feel ownership and pride. Existing structures are improved and enhanced to build change through an evolutionary, rather than a revolutionary, approach. This approach is cost-effective and brings the best expertise of both developing countries and the international community together in a problem-solving format that can be rapidly scaled up to reach the poor quickly and effectively.

This process of participatory experimentation empowers the poor through knowledge generation and sharing. Through experimentation, the poor can investigate—and contribute to—the development of practical, affordable, and sustainable practices that are reliable and robust in their circumstances. The poor gain the information they need to select the best technology combinations for their conditions. They then share this knowledge with their fellow farmers through different channels, such as farmer field schools, field tours, and field days. Information from pilot project areas spreads widely and quickly across geographic and socioeconomic gradients. Experimentation is followed by diversification. After experimenting with different crops, farmers choose those that respond favorably to inputs or that perform well in their environments. They use an incremental adoption strategy. As their knowledge about a specific technology increases, as their farm produce increases, and as more profits accrue from the sales, farmers gradually expand their capacity to diversify into other production activities.

The key element is building the trust and respect of the poor. Trust and respect are gained through a continuing exercise of discussing and coming to a consensus on options, together with obtaining routine and informed feedback on results. Some tools are already in use. Researchers have been highly innovative in developing the necessary tools to meet the challenge of conducting participatory activities with many clients over an extended geographic area in a cost- and time-effective manner. See, for example, Snapp, Blackie, and Donovan's (2003) "mother and baby" trial design, which collects quantitative data from mother trials that are managed by researchers and systematically cross-checks them against baby trials that are managed by farmers. This approach quickly generates best bet options that are owned by the participating communities. Moreover, it creates a fertile environment for developing new insights and priorities. The eventual product has several advantages:

- It is owned by those who need to adopt it, so they have a genuine belief that it actually is useful.
- It builds bridges of communication between target communities and the agencies working to assist them (the chronic research-extension linkage problem).
- It creates a confidence among the target population that they can solve their own problems, leading to quicker innovation and also spread of innovation across communities.

In many of the success stories developed in the subsequent Investment Notes, the path was laid through skillful building of partnerships with farmers, communities, and institutions in the countryside.

LAND MANAGEMENT TRADE-OFFS

Land-use change has allowed civilizations to grow crops, feed livestock, obtain energy, build cities, and carry out myriad other activities that underlie material advancement of any society and progression through the other major societal transitions. Land-use change also profoundly alters ecosystems as vegetation is cleared and biomass is diverted for human consumption. Unintended environmental consequences potentially undermine future land-use options.

Since publication of the Brundtland report (WCED 1987), the concept of sustainability has received increasing attention in agriculture, yet researchers have struggled to operationalize the concept. Smyth and Dumanski (1993) subdivided the general concept of sustainability into four main pillars: (a) productivity, (b) stability of production, (c) soil and water quality, and (d) socioeconomic feasibility. A slightly different approach for using the concept of sustainability has been to define various indicators (see, for example, Bockstaller, Girardin, and van der Werf 1997; Pieri and others 1995).

Several practical problems arise in implementing this strategy, including the large amount of data needed to quantify a large number of different sustainability indicators and the challenge of understanding the complex interactions among such indicators. Some researchers have combined indicators into indexes (for example, Farrow and Winograd 2001; Sands and Podmore 2000). This procedure raises the question of how indexes measured in different units can be meaningfully aggregated. The choice of "weights" used for such aggregation is often arbitrary and lacks adequate rigor. One well-known strategy for weighting different indexes was developed by economists for cost-benefit analysis, wherein systematic methods have been created to ascertain monetary values to attribute to both market and nonmarket goods and services, including services of natural capital. Yet even those systematic attempts to value and aggregate market and nonmarket goods have proved controversial and have not been widely accepted within and outside the economics profession (Belzer 1999; Portney 1994).

The alternative approach taken in trade-off analysis is to work with decision makers to identify a limited set of high-priority indicators and then to provide decision makers with quantitative estimates of the relationships among those indicators, leaving to the decision makers the task of subjectively assessing the implied trade-offs or win-win options. Trade-off curves are used to communicate information about trade-offs to decision makers. Trade-off curves are designed to embody the principle of opportunity cost in production systems. They are typically constructed by varying parameters in the production system that affect the economic incentives perceived by farmers in their land-use and input-use decisions.

A key potential benefit of the trade-off approach is the ability to model the desirability and likely effects of scaling up good practice. Most often, the scaling-up approach used is based on the simplistic assumption of additive economic and ecological benefits as one scales up good practice. The goal of trade-off analysis is to support decision making related to public policy issues associated with agricultural production systems. Thus, the focus of trade-off analysis is to provide information at a spatial scale relevant to such policy questions—typically at a level of analysis such as a watershed, a political unit, or a region, or even at the national level. Yet the environmental effects of production systems are generally site specific. A critical question, therefore, is how to bridge the gap between the site-specific effects of agricultural production systems and the scale relevant for policy decisions. The trade-off analysis model is designed to solve this problem by characterizing the population of biophysical and economic decision-making units in a region, simulating their behavior at the field scale, and then aggregating outcomes to a regional scale that is relevant for policy analysis by using trade-off curves and other means of communicating results.

CONFRONTING THE EFFECTS OF LAND USE

Current trends in land use allow humans to appropriate an ever-larger fraction of the biosphere's goods and services while simultaneously diminishing the capacity of global ecosystems to sustain food production, maintain freshwater and forest resources, regulate climate and air quality, and mediate infectious diseases. This assertion is supported across a broad range of environmental conditions worldwide, although some (for example, alpine and marine areas) are not considered in this sourcebook. Nevertheless, the conclusion is clear: modern land-use practices, while increasing the short-term supplies of material goods, may undermine many ecosystem services in the long run, even on regional and global scales.

Confronting the global environmental challenges of land use requires assessing and managing inherent trade-offs between meeting immediate human needs and maintaining the capacity of ecosystems to provide goods and services in the future. Assessments of trade-offs must recognize that land use provides crucial social and economic benefits, even while leading to possible long-term declines in human welfare through altered ecosystem functioning.

SELECTING AND USING APPROPRIATE INDICATORS FOR SLM AND LANDSCAPE RESILIENCE

SLM policies must also assess and enhance the resilience of different land-use practices. Managed ecosystems—and the services they provide—are often vulnerable to diseases, climatic extremes, invasive species, toxic releases, and the like. Increasing the resilience of managed landscapes requires practices that are more robust to disturbance and that can recover from unanticipated surprises. The need for decision-making and policy actions across multiple geographic scales and multiple ecological dimensions is increasing. The very nature of the issue requires such actions: land use occurs in local places, with real-world social and economic benefits, while potentially causing ecological degradation across local, regional, and global scales. Society faces the challenge of reliably assessing outcomes and developing strategies that reduce the negative environmental impacts of land use across multiple services and scales while sustaining social and economic benefits.

Indicators are interlinked components and processes in one land management system, not a group of separate variables. Although each indicator could be interpreted independently, SLM as a whole can be assessed only if its indicators are linked in a meaningful way. In the context of SLM, different biophysical and socioeconomic indicators of both a quantitative and a qualitative nature are selected, measured, and evaluated. This heterogeneous mix of indicators requires a qualitative frame or structural model for a meaningful analysis of the links between and causal effects of the indicators (box 1.3).

DIVERSITY OF LAND MANAGEMENT SYSTEMS AND POVERTY ALLEVIATION

For structure, the sourcebook follows the comprehensive 2001 Food and Agriculture Organization (FAO)–World Bank study, *Farming Systems and Poverty: Improving Farm-*

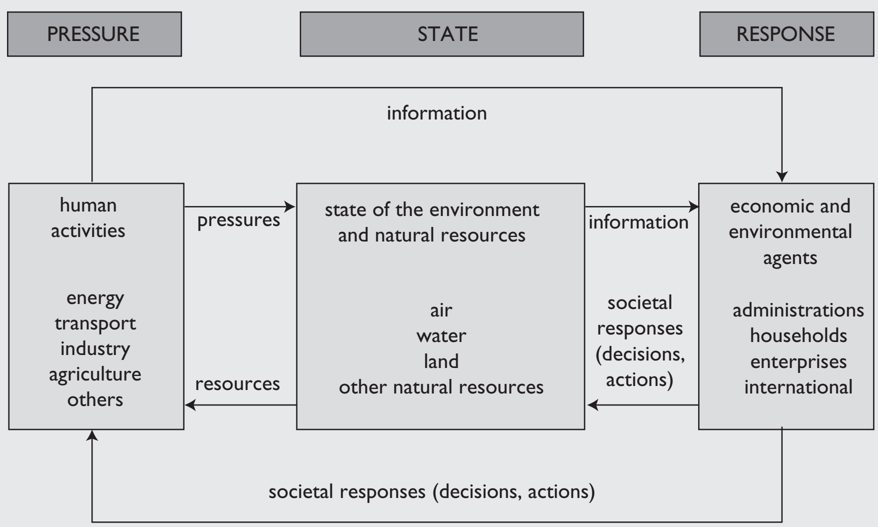
Box 1.3 Pressure-State-Response Framework

The framework shown in the accompanying figure can be used as a structural model for identifying core issues, formulating impact hypotheses, and selecting a meaningful set of indicators. The indicators are related to the components of the model.

The Sahara and Sahel Observatory in Tunisia identified four topics for coverage when developing impact indicators using the Pressure-State-Response framework:

1. *Driving forces causing pressure on natural resources.* These forces include population pressure, economic growth, and urbanization; policy failures or distortions (such as stagnant technology and delayed intensification); imperfect markets (including lack of markets and poor market access); transaction costs and imperfect information (including limited access to information about market opportunities); social inequity and poverty; and political and social instability.
2. *Pressure indicators.* These indicators include changes in cropping techniques, financial position of holdings, fuelwood and charcoal consumption, use of crop residues, use of animal dung for fuel, and price of fuelwood and charcoal.
3. *State indicators.* These indicators include rate of deforestation, rate of soil erosion, degree of salinization, soil crusting and compaction, crop productivity, livestock productivity, and nutrient balance (on-farm organic matter recycling).
4. *Response indicators.* These indicators include legislative change, investment, tree planting, state conservation programs, farmer conservation groups, and farmer adoption of tree planting and soil and water conservation.

Pressure-State-Response Framework



Source: Herweg, Steiner, and Slaats 1999.

ers' Livelihoods in a Changing World (Dixon and Gulliver with Gibbon 2001). The study adopted a farming systems approach to provide an agricultural perspective to the revision of the World Bank's rural development strategy. It drew on many years of experience in the FAO and the World Bank, as well as in a number of other national and international institutions. More than 70 major farming systems were defined throughout the six developing regions of the world. Findings were supported by more than 20 case studies from around the world that analyzed innovative approaches to small farm or pastoral development. Although recognizing the heterogeneity that inevitably exists within such broad systems, the farming systems approach provides a framework for understanding the needs of those living within a system, the likely challenges and opportunities that they will face over the next 30 years, and the relative importance of different strategies for escaping from poverty and hunger.

The key farming system types identified and described by the study (Dixon and Gulliver with Gibbon 2001) are briefly summarized here to guide and focus the interventions and investment examples and guidelines.

Overview of Farming Systems as a Baseline for Targeting Investments

A *farming system* is defined as a population of individual farm systems that have broadly similar resource bases, enterprise patterns, household livelihoods, and constraints and for which similar development strategies and interventions would be appropriate. Depending on the scale of the analysis, a farming system can encompass a few dozen or many millions of households.

The delineation of the major farming systems provides a useful framework within which appropriate agricultural development strategies and interventions can be determined. The classification of the farming systems of developing regions has been based on the following criteria:

- *Available natural resource base.* Classification takes into account water, land, grazing areas, and forest; the climate (altitude is an important determinant); the landscape (slope is considered); and farm size, tenure, and organization.
- *Dominant pattern of farm activities and household livelihoods.* Classification takes into account such factors as field crops, livestock, trees, aquaculture, hunting and gathering, processing, and off-farm activities. The main technologies used determine the intensity of production and integration of crops, livestock, and other activities.

On the basis of those criteria, 8 broad categories of farming system and 72 farming systems have been identified:

1. Irrigated farming systems (3), embracing a broad range of food and cash crop production
2. Wetland rice-based farming systems (3), dependent on monsoon rains supplemented by irrigation
3. Rainfed farming systems in humid and subhumid areas of high resource potential (11), characterized by crop activity (notably root crops, cereals, industrial tree crops—both small scale and plantation—and commercial horticulture) or mixed crop-livestock systems
4. Rainfed farming systems in steep and highland areas (10), often characterized by mixed crop-livestock systems
5. Rainfed farming systems in dry and cold areas (19), characterized by mixed crop-livestock and pastoral systems merging into sparse and often dispersed systems with very low current productivity or potential because of extreme aridity or cold
6. Dualistic farming systems with both large-scale commercial and smallholder farms (16) across a variety of ecologies and with diverse production patterns
7. Coastal artisanal fishing and farming systems (4)
8. Urban-based farming systems (6), typically focused on horticultural and livestock production.

The eight categories of farming system are further compared in table 1.1, which shows the areas of total land, cultivated land, and irrigated land; agricultural population; and market surplus. A recent study investigating alternative household strategies for land management (farming) systems in developing countries reinforced the need for greater development attention to diversification and intensification (box 1.4). In the relatively constrained circumstances of rainfed highlands and rainfed dry or cold climates, however, off-farm employment and exit from

Table 1.1 Comparison of Farming Systems by Category

Category characteristic	Irrigated systems	Wetland rice-based	Rainfed humid	Rainfed highlands	Rainfed dry and cold	Dualistic (large and small)	Coastal artisanal fishing	Urban-based
Number of systems	3	3	11	10	19	16	4	6
Total land (million hectares)	219	330	2,013	842	3,478	3,116	70	—
Cultivated area (million hectares)	15	155	160	150	231	414	11	—
Cultivated area/total area (%)	7	47	8	18	7	13	16	—
Irrigated area (million hectares)	15	90	17	30	41	36	2	—
Irrigated area/cultivated area (%)	99	58	11	20	18	9	19	—
Agricultural population (million)	30	860	400	520	490	190	60	40
Agricultural persons/cultivated area (person/hectare)	2.1	5.5	2.5	3.5	2.1	0.4	5.5	—
Market surplus	High	Medium	Medium	Low	Low	Medium	High	High

Source: FAO data and expert knowledge.
Note: — = not available. *Cultivated area* refers to both annual and perennial crops.

Box 1.4 Household Strategies to Improve Livelihoods

Several strategies can help households improve their livelihoods:

- Intensify existing farm production patterns through increased use of inputs or better-quality inputs.
- Diversify production, with emphasis on greater market orientation and added value, involving a shift to new, generally higher-value products.
- Increase farm size (an option limited to a few areas where additional land resources are still available).
- Increase off-farm income to supplement farm activities and provide financing for additional input use.
- Exit from agriculture, in many cases by migrating from rural areas.

Source: Dixon and Gulliver with Gibbon 2001.

agriculture are important (though not always easy to achieve).

Principles for Sustainable Land Management in Rainfed Farming Systems

For rainfed systems, a number of studies (including Dixon and Gulliver with Gibbon 2001) have identified a set of principles. According to these studies, good land management requires an integrated and synergistic resource management approach that embraces locally appropriate combinations of the following technical options:

- Buildup of soil organic matter and related biological activity to optimum sustainable levels for improved moisture, infiltration and storage, nutrient supply, and soil structure through the use of compost, farmyard manure, green manures, surface mulch, enriched fallows, agroforestry, cover crops, and crop residue management
- Integrated plant nutrition management with locally appropriate and cost-effective combinations of organic or inorganic and on-farm or off-farm sources of plant nutrients (such as use of organic manures, crop residues, and rhizobial nitrogen fixation; transfer of nutrients released by weathering in the deeper soil layers to the surface by way of tree roots and leaf litter; and use of rock phosphate, lime, and mineral fertilizer)
- Better crop management using improved seeds of appropriate varieties; improved crop establishment at the beginning of the rains (to increase protective ground cover, thereby reducing water loss and soil erosion); effective weed control; and integrated pest management
- Better rainwater management to increase infiltration and eliminate or reduce runoff so as to improve soil moisture conditions within the rooting zone, thereby lessening the risk of moisture stress during dry spells, while reducing erosion
- Improvement of soil rooting depth and permeability through breaking of cultivation-induced compacted soil layers (hoe or plow pan) by means of conservation tillage practices (using tractor-drawn subsoilers, ox-drawn chisel plows, or hand-hoe planting pits or double-dug beds or interplanting deep-rooted perennial crops, trees, and shrubs)
- Reclamation, where appropriate (that is, if technically feasible and cost-effective), of cultivated land that has been severely degraded by such processes as gullying, loss of topsoil from sheet erosion, soil compaction, acidification, or salinization.

These good SLM principles are used to derive the lending directions suggested in the next section. They are also a basis for the Investment Notes and Innovative Activity Profiles presented for potential application in areas with rainfed farming systems.

FUTURE DIRECTIONS FOR INVESTMENTS

Public and private investments to intensify sustainable production systems are generally best focused on the following:

- Facilitating the capacity of farmers, the government, and the private sector to make decisions about the appropriate technological and resource allocation
- Providing the necessary social, organizational, and physical infrastructure.

It is critical that agricultural production systems be sufficiently flexible to adapt to changing environmental and economic conditions.

New technologies will be developed, and variations on established production systems are likely to continue. At present, options that may warrant public sector support include the following:

- Improvement of plant varieties will remain crucial as it becomes increasingly difficult to adjust the environment to the plant. Plant varieties that are adapted to specific production environments and sustainable agricultural practices and that are resistant to specific pests and diseases will become increasingly important. Livestock improvement will increase productivity and make more efficient use of scarce land and water. Biotechnology's potential as a tool for sustainable production systems should be evaluated and supported on a case-by-case basis.

- Conservation farming practices can reduce unnecessary input use. Minimum tillage or no-till crop production reduces labor and equipment costs, enhances soil fertility, reduces erosion, and improves water infiltration, thereby reducing unit costs and conserving land resources. Improved crop residue management, including mulching, is often a necessary component of these systems. No-till systems of conservation farming have proved a major success in Latin America and are being used in South Asia and Africa.
- Organic farming eliminates use of chemical inputs and can be sustainable as long as practices maintain productivity at a reasonable level, consistent with price incentives provided by growing market opportunities for organic produce. Organic farming depends mainly on the development of niche markets with reliable standards and certification systems for production.
- Integrated pest management (IPM) systems have been developed for many crops to control pests, weeds, and diseases while reducing potential environmental damage from excessive use of chemicals. Scaling up IPM technologies is a challenge, as these management systems rely on farmers' understanding of complex pest ecologies and crop-pest relationships. Thus, although IPM messages need to be simplified, IPM systems require continuous research and technical support and intensive farmer education and training along with policy-level support.
- Precision agriculture improves productivity by better matching management practices to local crop and soil conditions. Relatively sophisticated technologies are used to vary input applications and production practices, according to seasonal conditions, soil and land characteristics, and production potential. However, with help from extension and other services, resource-poor farmers can also apply principles of precision agriculture for differential input application and management on dispersed small plots. Appropriate technologies suitable for use by small-scale farmers include simple color charts to guide decisions on fertilizer application and laser leveling of fields for irrigation.
- Fertilizer use is relatively low, especially in Africa, and soil fertility is declining, which explains much of the lagging agricultural productivity growth in Africa relative to other regions. Fertilizer use is resurfacing on the African development agenda, and policy makers face a major challenge in deciding how to promote increased use of mineral fertilizers. Several obstacles must be overcome to avoid fertilizer market failure, however. They include the strong seasonality in demand for fertilizer, the risk of using fertilizer stemming from weather-related production variability and uncertain crop prices, the highly dispersed demand for fertilizer, a lack of purchasing power on the part of many potential users, the bulkiness and perishability of most fertilizer products, and the need to achieve large volumes of throughput in fertilizer procurement and distribution to capture economies of scale.

Agricultural intensification is a key and desirable way to increase the productivity of existing land and water resources in the production of food and cash crops, livestock, forestry, and aquaculture. Generally associated with increased use of external inputs, *intensification* is now defined as the more efficient use of production inputs. Increased productivity comes from the use of improved varieties and breeds, more efficient use of labor, and better farm management (Dixon and Gulliver with Gibbon 2001). Although intensification of production systems is an important goal, these land management systems need to be sustainable to provide for current needs without compromising the ability of future generations to meet their needs.

Some of the system adaptations that are options for sustainable intensification of production include the following:

- Integrated crop-livestock production can enhance environmental sustainability by feeding crop residues to animals, thus improving nutrient cycling. This crop-livestock approach is likely to become increasingly profitable given the large, worldwide increase in demand for meat, milk, and other products derived from animals. The suitability of many livestock enterprises to the production systems of small farms holds considerable potential for poverty reduction.
- Agricultural diversification must be pursued where existing farming systems are not environmentally sustainable or economically viable. Diversification into high-value, nontraditional crop and livestock systems (for example, horticultural crops) is attractive because of the growing market demand for these products, their high labor intensity, and the high returns to labor and

management. In contrast to other low-input strategies for sustainable intensification, diversification to high-value products frequently requires the use of relatively high levels of inputs, which must be monitored and managed carefully.

- Tree crops, including fruit, beverage, timber, and specialty crops, offer opportunities for environmentally sound production systems because they maintain vegetative cover and can reduce soil erosion. Tree crops, especially when multiple species are planted, help maintain a relatively high level of biodiversity. They are important for export earnings in many countries and, although often suited to large-scale plantations, are also important to smallholders with mixed cropping systems.

Both public and private investments are needed to support the transition to more profitable and sustainable farming systems. Sustainable intensification will frequently require activities that provide an enabling environment and support services for the market-led changes or component technologies, including management practices. Much investment will come from market supply chains based in the private sector, including input supply and output marketing and processing enterprises and farmers. Public investment will need to focus on (a) new knowledge and information services, (b) public policy and regulatory systems, and (c) market and private sector development.

A key investment area is in technology associated with management innovations to improve overall productivity and sustainability of agricultural systems. Much research will focus on developing improved management systems, with an emphasis on understanding agricultural ecology, farm management, and social systems. Biotechnology offers opportunities to diversify and intensify agricultural production systems: tissue culture for production of virus-free planting stock (such as bananas) and transgenic crops with pest resistance or other beneficial characteristics.

Because of the larger spatial and temporal scales of operations and likely effects of landscape and watershed investments relative to a single site or community project, certain difficulties must be overcome. For example, successfully scaling up site-specific SLM innovations invariably requires negotiated implementation arrangements suited to local power structures and institutions. Safeguard policies are often critical to SLM and natural resource management investments. The key policies of the World Bank are identified in box 1.5.

Box 1.5 Key Safeguard Policy Issues for SLM and Natural Resource Management Investments

The World Bank has implemented the following policies with respect to SLM and natural resource management investments:

- *Environmental assessment (Operational Policy/Bank Procedure 4.01).* An environmental assessment is required if a natural resource management project has potential for adverse environmental risks or impacts.
- *Natural habitats (Operational Policy 4.04).* Protection of natural habitats (land and water areas where most of the original plant and animal species are still present) is required for any natural resource management investment that may cause degradation of the habitat.
- *Projects in international waterways (Operational Policy 7.50).* The borrower must notify other riparian countries of any proposed natural resource management investment involving a body of water that flows through or forms part of the boundary of two or more countries.
- *Involuntary resettlement (Operational Policy/Bank Procedure 4.12).* A resettlement action plan is required if a natural resource management investment results in physical relocation, results in loss of land or access to land or other assets, or impacts on livelihoods arising from restrictions on access to parks or protected areas.
- *Indigenous peoples (Operational Directive 4.20).* An indigenous peoples action plan is required if a natural resource management investment affects indigenous people.
- *Forestry (Operational Policy 4.36).* Government commitment to undertake sustainable management and conservation-oriented forestry is required for any investment with potential to have a significant impact on forested areas. (Investment with exclusive focus on environmental protection or supportive of small-scale farmers may be appraised on its own merits.)

Source: World Bank 2005b.

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