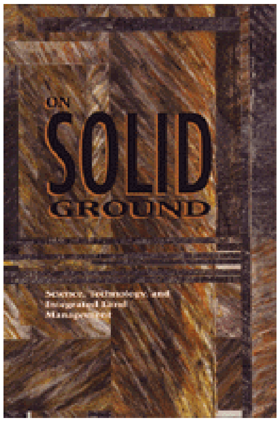
ON SOLID GROUND
Science, Technology, and Integrated Land Management



Panel on Integrated Land Management

United Nations Commission on Science and Technology for Development

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Contents

Foreword

The history of humanity is essentially linked to the management of the Earth's surface. In the beginning, unknown variables and the environment controlled the nature of human settlements. Today, as we approach the end of the second millennium, the uncontrolled expansion of human settlements is modifying the environment and seriously threatening the sustainability of the whole planet. Human activity is likely one of the most powerful causes of infertile soils, changing climates, and losses in natural beauty and biological diversity. In the beginning, it was nature against humanity; now, it seems, it is humanity against nature.

At the dawn of the 21st century, we have rediscovered the need for a harmonious and holistic approach to our relationship with the Earth. Land cannot be the master, but neither can it be the slave. Land is a garden to be managed, but no garden can be managed without gardeners.

Land management has been revisited in a multidimensional vision for preventive and curative action. Integrated land management (ILM) is a holistic approach that identifies the stakeholders and their needs; comprehensively evaluates options for people and nature to find ones that meet the needs of both on a long-term basis; and integrates solutions to human, economic, and environmental problems.

ILM is not only a tool for sustainable development but also a new way of thinking. It is an essential component of the Spirit of Rio, which produced the extraordinary Agenda 21 in 1992 — a symbol of the new paradigm, emerging from the consensus of the more than 180 countries committed to reversing the dangerous trends toward unsustainable use of the Earth's resources.

ILM and participation are two sides of the same coin, from the grass roots up to the top decision-makers of a region or country. ILM integrates knowledge derived from the sciences and the social sciences with the wisdom of local communities, indigenous peoples, women, and others who for centuries built strategies for life and survival, who cared about the future of their mother Earth.

ILM and information are also two inseparable concepts, but they need stronger North–South and East–West linkages. These linkages will open up new ways of communicating experiences and technologies and integrating a global solution in a world grown small, so small that minor problems on any part of the Earth's surface now affect the entire future of humanity on Earth.

The scientific and technological solutions are there, but the problems are growing more serious. Isn't it time to abandon narrowly focused perspectives? The moment has arrived — we must accelerate the shift toward ILM.

The Commission on Science and Technology for Development (CSTD) recognized the important role it could play in promoting an integrated approach to land management. This publication is the outcome of the work of CSTD's Panel on Integrated Land Management, which received input from experts from many countries and the relevant organizations of the United Nations system. Our expectation was that we could add to the efforts of people around the world who are concerned about the future of our common home.

Oscar Serrate
Chair
United Nations Commission on Science and
Technology for Development

Preface

In Agenda 21, adopted at the United Nations Conference on Environment and Development in Rio de Janeiro, Brazil, in 1992, a discussion of deforestation, desertification, drought, mountain-development, agriculture, rural-development, and biodiversity issues is preceded by an overview of an “integrated approach to the planning and management of land resources” (UN 1992). In 1995, chapter 10 was reviewed at the third session of the Commission on Sustainable Development (CSD), during the first cycle of CSD’s multiyear program of work.

The Commission on Science and Technology for Development (CSTD), at its first session in 1993, selected three themes to be the focus of its panels’ work during the 1993–95 intersessional period. Because the CSTD recognized that integrated land management is an area in which science and technology (S&T) could play a significant role, “the contributions of S&T to an integrated approach to land management” was chosen as the theme for one of the three panels, the Panel on Integrated Land Management. In 1994, while the Panel’s work was in progress, the Economic and Social Council called for closer linkages between different legislative bodies, which added an incentive for cooperation with CSD.

The membership of the Panel — experts from China, Colombia, India, Malaysia, the Netherlands, Pakistan, Philippines, Tanzania, the United States, and the Food and Agriculture Organization of the United Nations — was well balanced, having both land-management specialists and the CSTD members with broader S&T policy perspectives. Technical and other valuable support was provided by the staff of the secretariats of CSTD and CSD.

The Panel met three times during 1994–95. In accordance with the given schedule, the work of the Panel was completed in January 1995, in time to make a contribution to the Ad Hoc Intersessional Working Group on Sectoral Issues of the CSD, which met in February 1995. The report of the Panel, which, as its chair, I presented, was well received and was taken into account in the deliberations of the Working Group. The Panel report was again made available to CSD at its session in April 1995 and was also submitted to CSTD’s second session in May 1995.

This successful cooperation between CSTD and CSD serves as a good model, as well as an incentive, for future joint activities between the two commissions.

J. Dhar
Chair, Panel on Integrated Land Management
United Nations Commission on Science and
Technology for Development

Acknowledgments

This publication is the outcome of 2 years of sustained and coordinated work by the Panel on Integrated Land Management of the Commission on Science and Technology for Development (CSTD) of the United Nations. As the Panel's chair, I would like to thank all the members of the Panel (see Appendix 1) for actively participating in this process and for contributing their valuable expertise and experience. I would like to extend my appreciation to Michael Huston for his efforts in putting together the various inputs, for his own substantial contribution in preparing the background material that facilitated the Panel's work, and for his help assuring the quality of the overall report. I also thank Hendrik Breman and Denis Sims for their valuable inputs and for their expertise, which helped shape and direct the Panel discussions.

Special acknowledgment is due to the Government of the Netherlands, in particular the Netherlands Ministry of Foreign Affairs, for the generous financial contribution that made the work of this Panel possible. Thanks are also due to the Institute of New Technologies of the United Nations University for hosting one of the Panel's meetings. I also acknowledge Canada's International Development Research Centre (IDRC) for its kind cooperation and for its support in making this publication possible.

It is also my pleasure to acknowledge on this occasion the effective cooperation between the United Nations Conference on Trade and Development (UNCTAD) and the Department for Policy Coordination and Sustainable Development (DPCSD) of the United Nations, which serve as the respective secretariats of the CSTD and the Commission on Sustainable Development (CSD): this cooperation facilitated the work of the Panel. Finally, I would like to acknowledge the support provided by the staff of the two secretariats. In particular, I wish to extend my personal appreciation to Kwaku Aning of UNCTAD and Hiroko Morita-Lou of DPCSD for working closely with me and other Panel members to achieve our objectives.

J. Dhar
Chair, Panel on Integrated Land Management
United Nations Commission on Science and
Technology for Development

Introduction

The Need for Science and Technology in Land Management

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The relationship between science and technology is analogous to that between understanding the cause of a problem and doing something about it. One cannot solve a problem without understanding its cause, yet understanding the cause does not by itself solve the problem. Technology can be defined as the application of scientific knowledge to the solution of human problems.

Discussing the technology related to a specific issue implies that that issue is sufficiently understood at the scientific level to allow us to identify the causes of problems, as well as potential solutions. An emphasis on developing and implementing technologies related to integrated land management (ILM) is now more appropriate than undertaking more research. In most cases, there is enough scientific knowledge available to guide the solutions to the critical issues threatening the sustainability of human agricultural, industrial, social, and economic systems. Although scientific research will always be needed to refine technologies for sustainable use of specific resources (and to predict, detect, and mitigate the negative consequences of technologies, such as chlorofluorocarbons), our scientific understanding is currently sufficient to solve the major threats to global sustainability. What is lacking are the political commitment and infrastructure to implement the technological solutions already identified.

This report identifies the major technologies (and supporting sciences) needed for an integrated approach to land management. Effective ILM is essential to ensure the sustainability of the environment and the Earth’s natural resources. Drawing on experiences from countries around the world, the members of the Panel on Integrated Land Management have identified the major technological needs for sustainable land management, the impediments to implementation of proven land-management technologies, and the approaches to overcoming these impediments.

Although the recommendations of this report must be broad and applicable to many different situations, it must be kept in mind that most land-management problems, and thus their solutions, have unique local properties. What works in one country or under one set of conditions will not necessarily work in all countries or under all conditions. Understanding and compensating for these local differences are key to achieving sustainable land-use management. The following comments address a few components of this local variability and may help illustrate the challenges and opportunities for sustainably managing the Earth’s resources.

The term “sustainability” has been used in a variety of ways and has no unequivocal definition (Kruseman et al. 1993), but the general concept involves a number of components related to maintaining and improving all aspects of the human condition, from health, to economic security, to a clean and pleasant natural environment. These components of sustainability include the following:

- Maintenance of desired conditions and levels of production of desired natural and manufactured goods;
- Efficient conversion of raw materials to end products, with a minimum of waste;
- Stability of desired conditions and production rates around their average; and

- Recovery of desired conditions and production rates following major disturbances (Fresco and Kroonenberg 1992).

These components of sustainability are applicable at scales ranging from farmers' fields to the entire globe and to issues ranging from ecosystem processes to agricultural and industrial productivity. Although some factors are most important at particular scales or for particular issues, strong commonalities run across all scales and issues. Maintaining ecosystem functions is recognized as being essential to a healthy economy (OSTP 1994), and the increasing global population magnifies local problems to global proportions.

The primary threats to global sustainability today include many of the same factors that have caused the collapse of governments and the disappearance of civilizations throughout the course of human history. Societies have collapsed for two basic reasons:

- The self-destruction of their resource base, primarily the soils that support agriculture; and
- Cimatic fluctuations to which societies cannot adapt rapidly enough (Hyams 1952).

Soils are continually being created by natural processes, but the rate at which this occurs is so slow that soils must be considered nonrenewable resources. Climatic fluctuations, as manifested by droughts and floods over short time scales and by ice ages over longer time scales, are an inherent feature of our planet and will continue to occur, with or without anthropogenic influences.

Fortunately, the understanding and technological tools to prevent the destruction of soils and even to improve critical soil properties are available, given the political and social will to use them. Our understanding of natural-system processes and technological solutions can be used to reduce the negative effects of short-term climatic fluctuations, and continuing improvement in weather forecasting will improve our ability to adapt to these natural variations in environmental conditions.

Fundamental constraints on land use

The primary difficulty in applying existing technological solutions to environmental, social, and economic problems is the great spatial and temporal variability of environmental conditions. A technology effective at one location may be totally ineffective at another. Likewise, something that works well in one decade may not work at all in another. Before we can successfully apply technology in support of sustainability, we need to understand the consequences of spatial and temporal variations in soils and climate. Without this scientific knowledge and the information technologies for distributing and interpreting this knowledge, the effective implementation of ILM and land-use technologies is virtually impossible.

Because sustainability concerns primarily the use of resources in agriculture, industry, and society, planning for sustainability must be based on knowledge of the current distribution of these resources. The global distribution of natural resources imposes limitations on all forms of development and sustainability that may be independent of the distribution of technology, manufactured goods, and the other products of human society.

Lack of freshwater is the major environmental constraint on agriculture, industry, and the progress of human societies. Although global patterns of rainfall and rainfall variability are well documented, our ability to predict shortages or excesses of rainfall is severely limited. Appropriate technologies can be used to ameliorate the effects of low rainfall or short-term drought, but extreme floods and severe droughts are beyond the scope of technology. Water availability imposes strong constraints on technologies for sustainability, and even subtle variations in the distribution of rainfall can have a major impact on the sustainability of various types of agricultural systems (Ellis and Galvin 1994).

The highest priority must be given to technologies for protecting, conserving, and efficiently using available surface and subsurface waters and rainfall. The resolution of water issues has benefits across many scales, ameliorates diverse social, economic, and ecological situations, and generates many win–win outcomes.

The next most important constraint on the progress of human society is soil, particularly the chemical and physical properties of soil that influence its agricultural (and ecological) productivity. The survival of all land animals, including humans, depends on plants that grow in the soil. Human economies and natural ecosystems are thus inextricably linked because both depend on plants that grow in soil.

Although humans can improve the physical and chemical properties of soils through their agricultural activities, by far the most common effects of human activities on soils are degradation and destruction. Many of the great societies in history, such as those of Greece, Crete, and the pre-Columbian New World, collapsed because they destroyed the soils supporting their populations (Hyams 1952). Humanity's positive and negative effects on the soil notwithstanding, soil properties are not uniformly distributed over the globe. Geological parent material influences the properties of young soils, but it is climate that determines the global distribution of the soil properties that influence plant productivity. The combination of warm temperatures and abundant precipitation speeds the chemical and biological processes that cause soils to develop, age, lose nutrients, and become more acidic (Sanchez 1976).

The consequence is that soils nearer the equator, where warm temperatures and high precipitation prevail, tend to have lower levels of essential plant nutrients than soils in the higher latitudes of the temperate zone. The global pattern of soil fertility (specifically, the availability of essential plant nutrients) is a latitudinal gradient, with fertility decreasing toward the equator. This soil-fertility gradient may underlie the latitudinal gradient of decreasing crop productivity (Figure 1) and decreasing monetary value of crops toward the equator (Huston 1994). Areas of high soil fertility do exist in the tropics, though, particularly in areas with volcanic activity and along rivers that drain young mountain ranges. Such areas of high soil fertility are of great agricultural and economic importance, and most have been developed for agriculture for hundreds or thousands of years.

Among the major tropical regions, great variation occurs in the proportions of soil types (Figure 2). South America has the smallest proportion of potentially fertile soils and the largest proportion of leached, low-nutrient soils. Africa and Asia have intermediate proportions of potentially fertile and infertile soils, whereas Central America's proportion of potentially fertile soils is similar to that of the United States, in temperate North America. The variation in proportions of fertile and infertile soils is greater between countries within these major continental regions than between the continents. Similarly, within any single country, the potential fertility of the soils can vary greatly from state to state.

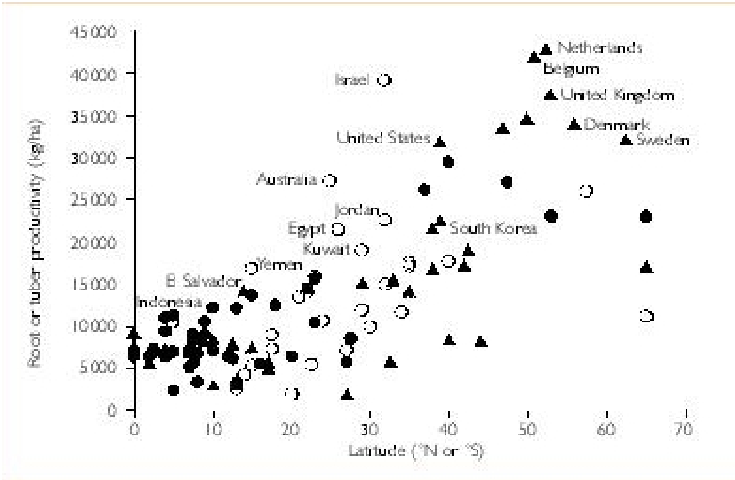

Figure 1. Root-crop productivity (sugar beet, manioc, yam, etc.) vs latitude and annual precipitation (○, <55 cm/year; ▲, 55–130 cm/year; •, >130 cm/year). Note the latitudinal gradient. The country with the highest value at any latitude also has nonagricultural sources of resources, usually petroleum. Source: Data from the Food and Agriculture Organization of the United Nations, as cited in Huston (1994).

Variations in the amount and pattern of precipitation and in the slope of the land surface interact to produce dramatic variations in runoff and soil-erosion rates (Figure 3). The hydrologic processes that create runoff and erosion also link soil and water, the two most critical resources for human survival. Because the choice of land use (for example, cultivation, pasture, or forest) also has a major influence on runoff and erosion (see Figure 3), any land-use practices that reduce runoff have the double benefit of increasing the local water supply and reducing soil loss.

These variations in soil fertility and in properties related to runoff and erosion impose limitations on the agricultural and land-management technologies that can be used and on the sustainable levels of productivity that can be achieved. Each continent and country has a unique combination of conditions requiring locally appropriate solutions.

Because many of the soil properties that influence agriculture also influence natural ecosystems, integrated land-use planning that is based on soil properties can address a variety of socioeconomic and conservation issues. That the distribution of soil resources should be a major consideration in land-use planning at all scales is suggested by the similarity in the latitudinal distributions of agricultural productivity and per capita income (Figure 4). Whether or not per capita income actually reflects a causal relationship between soils and national economies, it is surely significant that countries near the equator, where agricultural productivity tends to be low, depend heavily on agriculture as a major component of their economies (Figure 5).

If technology is to successfully support the components of sustainable development, there must clearly be an understanding of the limitations imposed by the current distributions of resources, especially soils and rainfall. Computer-based information technologies, national and international databases, and satellite imagery provide the technological foundation for integrated land-use planning.

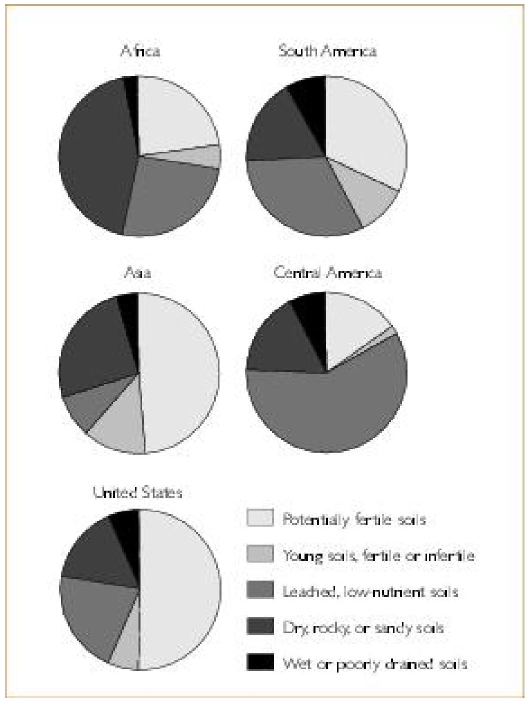

Figure 2. Proportions of different soil types in four major continental regions of the tropics, with the United States given for comparison. Note that South America has the lowest proportion of potentially fertile soil, in contrast to Central America, which has the highest. Source: Data in Richter and Babbar (1991).

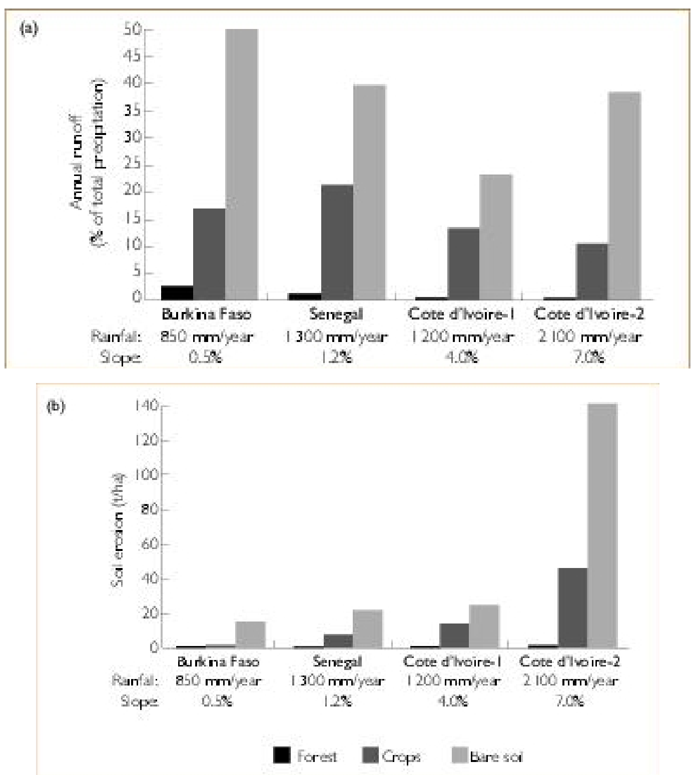

Figure 3. Effect of precipitation, land-surface slope, and land use on (a) runoff and (b) soil erosion at four locations in West Africa. Note that water infiltration is always much higher and erosion losses are always much lower with forest than with crops or bare soil, particularly on steeper slopes with high rainfall. Source: Data in Charreau (1972), as cited in Sanchez (1976).

Multiple benefits from land-use planning

Integrated land-use planning depends on proper evaluation of the potential of every unit of the landscape to sustainably support the many services society needs. Every unit of a landscape has the potential to perform several functions, which might be contributing to agricultural or industrial productivity, maintaining biodiversity, and minimizing the runoff. Information on the physical and biological properties of landscapes is available from soil surveys, topographic maps, and satellite images. However, using this information effectively requires both scientific understanding and technological infrastructure.

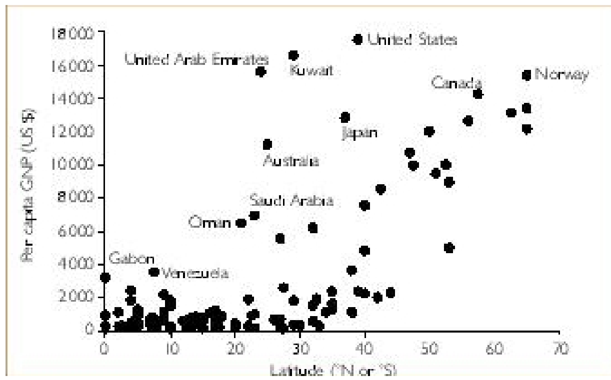

Figure 4. Average economic conditions of individuals (expressed as per capita gross national product) vs latitude. Note the latitudinal gradient. Source: Data from the Food and Agriculture Organization of the United Nations and the World Bank, as cited in Huston (1994).

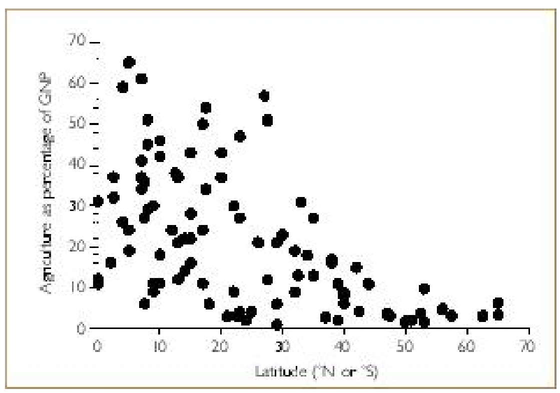

Figure 5. Economic contribution of agriculture to gross national product. Note the latitudinal gradient. Source: Huston (1994).

Integrated land-use planning must take into consideration all of the functions performed by the different landscape components of an area, and the area must be large enough that the economic and ecological interactions of the landscape components can be determined as well. The economic interchanges between urban and rural areas, for example, affect the value of the goods and services supported by the land (Jacobs 1984). The movement of surface and subsurface water, air masses, and their chemical constituents establishes physical linkages and ecological interactions.

Integrated land-use planning must be a multidisciplinary effort, using the expertise of hydrologists, economics, ecologists, social scientists, agronomists, foresters, etc. We already know which of the available technologies would likely contribute to the sustainability of a particular sector of human activity. What is still lacking is an understanding of the interactions between various sectors (for example, between agricultural production and biodiversity conservation; between water conservation and industrial development) and how land-use allocations can simultaneously produce positive results in several sectors. Because planning for sustainability must address multiple components of human and natural systems, land-use prioritizations must be based on proper evaluations of all the potential uses of each unit of land.

Multiple benefits from conserving biodiversity

One area in which ILM can produce multiple benefits is conservation of biological diversity. There is much evidence that many components of biodiversity thrive in marginal areas unsuitable for sustainable, productive agriculture. Thus, there is no inherent conflict between the goals of preserving much of the Earth's biodiversity and developing agricultural productivity to support human populations. However, some components of biodiversity, such as vertebrate herbivores and large predators, are more suited to the nonmarginal areas, most of which have been converted to agriculture. The inherent conflicts between human and natural uses of the landscape must be recognized and addressed so that preservation of much of the Earth's biodiversity can be accomplished without sacrificing the potential for sustainable agricultural productivity. Understanding the distribution of soil fertility and potential agricultural productivity is the key to planning for the preservation of biodiversity while simultaneously enhancing agricultural productivity (Figure 6).

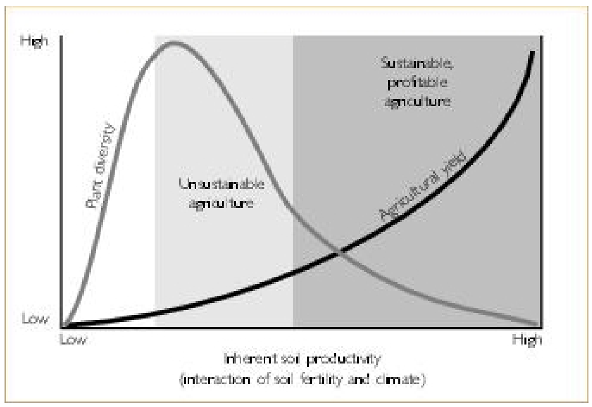

Figure 6. Expected relationship between agricultural productivity and plant-species diversity. Note that plant diversity is naturally low under conditions where agricultural productivity is highest. Sustainable agriculture is productive and does little damage to plant-species diversity. Unsustainable agriculture is unproductive and results in a great loss of plant-species diversity. Source: Adapted from Huston (1995).

Multiple benefits from using a technology

Many technologies can produce benefits for human society and biodiversity simultaneously. These benefits include protection of catchment basins, improvement in water quality, restoration of degraded lands, control of erosion, and prevention of pollution. Identifying locations where technology can produce multiple benefits should be a primary objective of ILM.

Many technologies can also contribute to efficient water use and soil conservation simultaneously. For example, rainfall is only available to plants if it infiltrates the soil rather than running off. Thus, in areas with low rainfall, increasing the infiltration rates and reducing the runoff are the primary goals of water management. At the same time, reducing the runoff also reduces erosion, thus conserving the soil (see Figure 3). Well-known technologies that increase infiltration and reduce erosion include maintaining a forest cover on steep slopes and along streams; using perennial crops where possible; plowing along contours; building terraces; and using vegetation, such as vetiver grass, to slow runoff and create natural terraces.

These water- and soil-conservation practices also reduce the severity of floods and raise the water table, which prolongs the availability of water during dry seasons and dry years. Soil-conservation practices that benefit agriculture, such as increasing the organic-matter content of the soil, also improve the ability of the soil to retain water. Additional benefits of these practices include improved water quality, which benefits aquatic organisms, as well as downstream urban and industrial users. Decreased erosion reduces sedimentation in shipping channels and may also have benefits for the marine fisheries of estuaries and coral reefs.

Many environmental problems result from having too much of a resource in one area or at one time and too little of it in another area or at another time. Floods and drought are a classic example. The severity of both floods and drought increases when the natural vegetative cover of a landscape is degraded. In addition to the damage floods cause along the river channels, the excessive input of freshwater may reduce the productivity of estuaries and other marine systems; likewise, insufficient input of freshwater during a drought can reduce the productivity of estuarine fisheries (SFEIWG 1994).

Another resource problem is the distribution of nutrients in soils — most agricultural systems are limited by nutrient availability. At the same time, the excessive concentrations of nutrients in urban and agricultural runoff and sewage severely pollute the water downstream, create health problems, and destroy aquatic biodiversity, along with recreational, commercial, and subsistence fisheries. These nutrients create further problems when they are discharged into the ocean. However, aquaculture technologies involving algae and fish are being developed to capture the excess nutrients in waste waters. The algae remove nutrients from the water and are then eaten by the fish, which convert the nutrients into protein and waste sediment that can be collected and used for fertilizer. Experiments in Texas with this newly patented technology demonstrated that this method is 10 times more efficient at removing nutrients than natural wetlands and produces fish protein and nutrient-rich sludge while purifying polluted water (Drenner et al. 1997). Analogous strategies in industrial processes reduce waste and convert it into valuable products. Technologies like this that produce multiple benefits are key to sustainability in all sectors of human activity.

The role of information technologies

To identify potential benefits and problems, land-use planners require sufficient information about the interaction of economic and ecosystem properties. Although much of this information is available in various forms, all of it must be in an integrated system to help in prioritizing and planning. Continuous improvements in the power and convenience of computer-based geographic information systems (GISs) are making an important contribution to land-use planning. Information from satellite imagery, as well as wider availability of satellite imagery, is essential for planning sustainable land use at all spatial scales.

Land-use planners also need computer models for extrapolating information from areas that are well understood to those about which little information is available. Models of hydrology and soil erosion that are based on fundamental principles can be widely applied: planners can insert basic information on topography, soil properties, and vegetative cover, much of which can be obtained from satellite imagery (O'Loughlin 1986; O'Loughlin et al. 1989; Vertessey and Wilson 1990; Beven and Moore 1993). Similarly, planners can use models of crop growth (for example, Keulen and Wolf 1986; Wolf et al. 1991) to estimate crop production under different soil and climatic conditions and to extrapolate data from experimental plots to larger regions.

Most of the scientific knowledge and technology needed to achieve global sustainability in agricultural and industrial systems is available. This report identifies why the needed technologies are not being used in land management and suggests ways to overcome the constraints on ILM.

Chapter 1

Challenges and Opportunities for Integrated Land Management

The increasing severity of the environmental, social, and economic problems experienced by both developed and developing countries has focused global attention on the sustainability of human activities. Because all current and future human activities depend, to some extent, on the Earth's surface — with its minerals, water, and other renewable and nonrenewable resources — ILM must become one of the primary tools of sustainable development. The concept of sustainable development combines the dual aims of improving the conditions for much of the world's population and providing for the needs of future generations. However, current land-management efforts to address a multitude of interrelated problems, including deforestation, desertification, air and water pollution, and uncontrolled expansion of human settlements in urban and rural areas, are hindered by a piecemeal and uncoordinated approach, often with duplication of effort or conflicting sectoral goals. A more holistic and integrated approach holds the prospect of solving several problems within a single, coherent framework.

The goal of ILM is to optimize the land's economic and environmental benefits for today's society while preserving or increasing its capacity to provide these and other benefits for future generations. The ILM approach is based on the recognition that land serves a variety of functions; that there are competing or conflicting needs for land; that more than one sector of society has interests in every land-use decision; and that diverse social, economic, and environmental considerations influence current and future land uses. By logically examining all potential land uses, ILM makes it possible to simultaneously

- Minimize conflicts over competing land uses;
- Use the land efficiently for maximum benefit;
- Improve social and economic development; and
- Protect and enhance the environment.

ILM is a prerequisite for sustainable development.

Furthermore, all aspects of science and technology (S&T) for land-use management should emphasize opportunities to reduce gender inequities — in many developing countries, women bear a disproportionate burden of land-related activities.

Elements of an integrated approach to land management

An integrated approach to land management identifies the social, economic, and environmental requirements of all stakeholders in society; develops possible land-use options; and indicates the combination of options needed to optimally meet these requirements for the long term. The logical sequence of procedures in an ILM approach is the following:

1. Provide opportunities for stakeholders, including decision-makers, land-management planners, land users, landowners, and beneficiaries of land services, to identify their requirements and needs.
2. Collect information about the physical, social, and economic conditions of the land area, and use this information to evaluate current and potential land conditions.

3. Identify spatial planning units for the land area, as well as options for each unit in terms of use; long-term economic returns; input–output relationships; and predicted social, economic, and environmental impacts.
4. Provide opportunities for the stakeholders to discuss and reach a consensus on the optimum land-use and management system for each planning unit.
5. Establish the institutional, legislative, and cadastral infrastructure needed to implement the agreed-upon land uses and long-term land management.

The ILM approach is not a fixed procedure but a continuous, iterative process of planning, implementation, monitoring, and evaluation that strives to meet as many of society's economic, social, and environmental needs as possible without penalizing any sectors of society or sacrificing future benefits. The essential components of this approach are independent of scale and are therefore applicable at the global, national, district, village, and farm levels. However, although the basic technical ILM methodologies are already available, their application in many parts of the world is limited by training, financial, and institutional constraints. Access to appropriate technologies is key to effective ILM on a global scale.

Problems caused by poor land management

The failure to manage land resources in an integrated, holistic manner has led to a number of serious problems and barriers to sustainable development. Environmental problems are inevitably linked to social and economic problems, including unemployment, poverty, disease, and starvation. The main problems are the following:

- *Permanent destruction or degradation of the land's capacity to provide economic and environmental benefits* — Throughout the world, in both developed and developing countries, examples can be found of erosion, desertification, collapse of fisheries and other resource stocks, depletion of groundwater, salinization of soils, dumping of toxic mine wastes, and the extinction of species and loss of biodiversity. Degradation of the land's capacity to support human populations can also lead to uncontrolled urbanization, mass migration, and social conflicts.
- *Inefficient use of resources* — Without an integrated approach to land management, technologies are often used that are inappropriate for a particular region or type of land. For example, irrigation projects are developed in dry regions where agricultural production is actually limited by a lack of soil nutrients rather than by a lack of water. The use of valuable resources, such as fertilizers and pesticides, can be excessive, unnecessary, or even detrimental to agricultural efficiency and can lead to pollution and health problems in both rural and urban areas. Increasing costs for water purification and treatment of pollution-caused diseases are often borne by sectors of society that have had nothing to do with causing the pollution. The inefficient use of energy resources is a major impediment to sustainable development in all its aspects. Experience throughout the developing world has demonstrated that the most effective solutions to many land-use problems draw on a combination of local knowledge and advanced technologies.
- *Accumulating impacts* — In addition to the local and national damaging effects of poor land management, cumulative international problems are becoming more serious as the Earth's population increases. For example, acidification of freshwater lakes in Scandinavia is apparently caused by industrial air pollution

from northwestern Europe. Deforestation in Nepal and the surrounding mountains leads to flooding in the Ganges and other river systems that pass through countries downstream. In Europe, pollution of the Rhine by industries in upstream countries results in reduced water quality in downstream countries. Land degradation and desertification in some countries can lead to mass migrations, serious refugee problems, and even land degradation in neighbouring countries, particularly during periods of extreme climatic conditions.

Although the basic problems of land management around the world have many common features, local variations in environmental, social, and economic conditions require technological solutions specifically adapted to local conditions.

Unintentional effects of agricultural activities, such as vegetation loss or nutrient depletion, can result in erosion or desertification to the extent that the land loses its capacity to produce the desired agricultural products and other essential goods and services. At the other extreme, manufacturing and agricultural industries often inadvertently produce toxic or harmfully high concentrations of agricultural fertilizers and industrial chemicals that may be extremely beneficial at moderate concentrations. Most land-use problems can be understood in terms of this continuum from depletion to pollution. Because the concentration of resources generally requires the input of energy and use of advanced technologies, pollution problems tend to be most serious in developed countries and in countries in transition. In the absence of ILM, resource depletion and the associated land degradation can be serious in areas that depend on agriculture and forestry, in both developed and developing countries.

The high costs of soil erosion

Many of the damaging effects of land degradation are interconnected: the effects of a problem in one area cause a cascading chain of problems in other areas. For example, soil erosion resulting from inappropriate farming methods on steep slopes has the serious local effect of reducing the food production and economic output of the eroded lands. However, other local effects, such as landslides that block roads or rail lines, are damaging not only to agriculture but to many other components of the local economy. The soil lost from the eroded hillsides can pollute and clog rivers farther away, increasing the frequency and severity of floods, affecting navigation, and reducing the fish harvest on which some downstream communities may depend. Still more distant, where the river enters the sea, siltation may harm coral reefs and estuaries, damaging both subsistence and commercial fisheries.

Soil erosion is one of the major causes of reduced potential for food production in both developed and developing countries. For example, the United States has lost approximately one-third of its topsoil since farming began less than 300 years ago, and it continues to lose 12 t/ha per year, for a total loss of 50×10^6 t of plant nutrients each year. The Huang River of China is the most sediment-laden river in the world and annually carries 1.6×10^9 t of soil from China's rich farmlands into the East China Sea. In Brazil, the huge Paso Real reservoir in Rio Grande do Sul has lost 18% of its original volume in less than 8 years, and continuing input of sediment from soil erosion threatens to reduce the life of this 530-MW hydroelectric plant to less than 30 years. Eighty-six percent of the Andean Zone in Colombia has some degree of erosion, with 21% at a critical level. Throughout history, there are examples of societies that collapsed because their agricultural activities destroyed the productivity of their land. In the modern world, the future human and economic security of both developed and developing countries continues to be threatened by land degradation.

Land degradation is particularly critical in the developing countries of the tropical zone. Problems of food security and rural poverty are of urgent concern in many of these countries, where high populations and weak or unstable economies severely limit the economic resources available to each person, often exacerbating gender inequities. Although many of these developing countries possess valuable mineral and energy resources, their national economies depend much more heavily on agriculture than do the developed countries of the higher latitudes. This heavy dependence on agriculture for both food production and national economic output makes any degradation of the productive capacity of the land a serious impediment to meeting basic human needs and achieving sustainable development. The inherent irreversibility of most forms of land degradation and the critical importance of food resources for the Earth's future generations underscore the essential role of S&T in addressing land-degradation issues. To emphasize S&T in addressing these issues is not, however, to ignore problems related to urbanization, industrialization, and mining, all of which must be considered in integrated land-use planning and management.

Chapter 2

Contributions of Science and Technology to Integrated Land Management

Science involves the combination of information and understanding that allows one to predict the consequences of specific actions or events and thus to evaluate alternative actions or different options. Technology is the application of science to provide better options for achieving human objectives. The solutions to the complex, interacting issues of land management require contributions from the physical, biological, and social sciences. Fortunately, most of the basic scientific knowledge and applied technologies needed for ILM are already available (see Appendix 2). These include global satellite surveillance systems and powerful computer-based GISs, as well as other methods for planning and evaluating land use, reducing wind and water erosion, and increasing the productivity of the land. Some of these technologies have been well developed for many years, whereas others are currently undergoing rapid development. Several are already being applied to land-management problems around the world. However, in many cases, the critical technologies that are widely used in developed countries are not available in the developing countries, where they are most needed, which contributes to many of the environmental and socioeconomic problems currently experienced around the world. Even where technology and information are already available in developing countries, they are not at present optimally used because of ineffective information storage, retrieval, or sharing.

Scientific research to improve our understanding of specific land-management issues, to refine existing technologies, and to develop new technological capabilities is essential. The sciences and related technologies needed to implement an ILM program can be grouped into four general areas:

- Information sciences and technologies;
- Evaluation sciences and technologies;
- Application sciences and technologies; and
- Supporting technologies and infrastructure.

The first two areas of S&T contribute primarily to the planning and evaluation components of ILM, whereas the last two deal with implementation of specific land-management practices (to move from the current situation to the desired future condition). Each type of technology is supported by a number of different scientific disciplines, such as agronomy, applied physics, geology, ecology, and economics.

Information sciences and technologies

Accurate information in a form useful to all stakeholders is essential for ILM. Information technologies and their supporting scientific disciplines provide access to basic information about the current status, potential uses, and limitations of the land, as well as market and transportation conditions and other business information. These technologies include traditional cartography and statistical analysis, as well as remote sensing from satellites and airplanes, ground-based monitoring and surveys, socioeconomic information, and the computer databases that allow land users and decision-makers to access this information. Monitoring the status and changing conditions of land, water, and biotic resources, using traditional methods as well as advanced technologies, is an essential component of ILM.

Historical and current information about land conditions and land-use practices is often scattered and difficult to access comprehensively. Modern information technologies allow more effective use of traditional information sources and local knowledge by combining them with new information from advanced technologies. Computer-based information and analytical capabilities make ILM more feasible than it was in the past. Efficient collection and analysis of the most needed information are facilitated by a combination of digital databases and statistical methods that allow identification of critical processes and limitations.

Challenges and successes of land management in China

China, the world's most populous nation, has made effective use of its land resources, feeding 22% of the world's total population with only 7% of the world's total farmland. However, the growing population and agricultural intensification in China have led to a variety of environmental problems. Soil erosion is not only reducing current and future agricultural production but threatening water quality, navigation, flood control, and the generation of hydroelectric power. A vast system of reservoirs for flood control and water storage has been constructed. However, nearly one-quarter of the storage capacity of 408.6×10^9 m^3 has already been lost to siltation, and 22 major reservoirs have ceased to function (UNCSTD 1994). The Chinese government is making great investments in S&T related to agriculture, water conservation, and forestry through its university and extension services. China has addressed the problem of land degradation in harsh and marginal environments by providing governmental support for agricultural intensification, as well as for revegetation of degraded lands (Breman 1987). Massive reforestation efforts are well under way to control wind and water erosion — the largest ecological project in the world covers 42.4% of the territory of China. The Great Green Wall, a reforestation project parallel with the Great Wall of China, has reduced the duration of spring dust storms in Beijing by as much as 90% while increasing the soil moisture available for agriculture in the reforested regions (Parungo et al. 1994). The economic and technical support needed to ensure a decent and productive life for farm families in marginal lands is often more cost effective than creating employment for these families in urban areas and has the added benefit of fostering economically and ecologically sustainable land use in nearby productive regions. ILM efforts in China are likely to have a global effect, as well as local and national benefits.

The most impressive examples of advanced information technology are the satellite images of the Earth that indicate the conditions of the land and clarify the connections between different regions. Analysis of digital information from satellites and aerial photography allows us to accurately monitor land conditions over large areas and increases the value of traditional ground-based surveys of soil properties, land use, crop productivity, mineral resources, and land ownership. Around the globe, international boundaries — and even fences within farms — are visible from space owing to the different land uses on either side. Dissemination of this type of information in a form useful to all land-use stakeholders requires a number of different approaches.

The basic form of information needed for ILM is the map, either printed on paper in traditional formats or contained in computer-based GISs. Obtaining and analyzing this information are the first steps in identification of options for land management. Remotely sensed data have proven indispensable for

- Undertaking accurate soil surveys;
- Evaluating deforestation, desertification, mining impacts, and other forms of land degradation;
- Evaluating the response of natural vegetation and agriculture to variations in climate, such as droughts, monsoons, and freezes; and
- Determining actual land-use patterns, including urbanization and industrialization, as well as agriculture.

Satellite images used to evaluate land-use patterns in Colombia

Colombia encompasses a wide range of environmental conditions, from high montane regions to lowland rainforests and semi-arid savannas, each with unique environmental problems. To develop a coordinated, country-wide approach to land management, the National Geographic Institute (Agustin Codazzi) used satellite images to compare actual land uses with the most suitable land uses in each region. Analysis for land-use sustainability indicated that almost 69% of Colombia's land area is best suited for forestry but that only 49% is actually in forest. Cattle pastures occupy more than 40% of the land area, although only 16.8% of the land is suitable for raising cattle. Analyses like these help to identify land-use problems and the regional and national goals that are needed to develop a program of integrated land-use planning.

Satellite imagery provides a powerful vehicle for guiding land-use policies at the national, regional, and local levels. This information makes government policymakers aware of the large-scale impacts of local activities and provides a means of integrating local knowledge about effective land-use practices into a regional or national land-management framework.

Land users in market economies need accurate, up-to-date information on current and predicted market conditions, transportation and storage capabilities, and changes in regulations or other important factors. Long-distance educational programs can provide critical training in business practices and applications of technology in developing regions.

In developing countries that depend on agriculture, important products of land evaluation include information on the cropping or grazing systems that best suit the soils, climate, and other environmental, social, and economic factors, as well as information on the impacts of the agricultural systems on the land. The maximum sustainable productivity of these agricultural systems determines the land's ability to continuously support human populations (the carrying capacity). ILM allows sustainable agricultural productivity to be increased toward its theoretical maximum. For example, the Agroecological Zones project for Africa (FAO 1990a), run by the Food and Agriculture Organization of the United Nations (FAO) indicates that the continent could produce enough food, fibre, and fuel to support a population far greater than the current 500 million. However, it is evident that the continent is not adequately meeting the needs of even the current population. Meeting the basic human needs of Africa's population will require a strategy of continent-wide ILM that includes a major effort in soil conservation and restoration of degraded lands coupled with socioeconomic measures.

Planning for economic success in Botswana

Economic growth and environmental planning are closely connected in the African country of Botswana, which has had the highest rate of growth in gross national product of any country in the entire world. Careful economic and environmental planning, along with good fortune, have made Botswana a showcase of the developing world. Although diamonds and trade with the European Common Market dominate the economy, a long history of attention to land resources has laid the basis for strong growth in the livestock sector. A thorough evaluation of land potentials for grazing and cultivation, completed in the 1970s (Sims 1981), included recommended stocking rates for different regions. Despite the difficulties of improving food security in a climate with frequent droughts, the government has developed and implemented plans to maintain and strengthen rainfed agriculture by supporting rural communities during droughts and the recovery. A strong institutional framework for land-use planning is in place at both the national and the regional levels, with land-use planning groups in each of the districts corresponding to the eight tribal regions. Botswana's recent history suggests that a continuing government commitment to careful planning, along with implementation of new ILM technologies, will allow sustainable development of this country's land resources.

Evaluation sciences and technologies

Evaluation sciences and technologies enable us to interpret and evaluate information about the land and to determine which options will lead to the most desirable pattern of land use. These tools include statistical analysis; decision-support models, such as Interactive Multiple Goal Programming (IMGP); and computer simulation models for crop production, econometric analysis, environmental-impact analysis, and manufacturing design. All these tools facilitate communication among stakeholders and provide input into the sociopolitical process of prioritizing land-use alternatives.

Many of the decisions in ILM are socioeconomic and political and cannot be resolved by technology alone. Alternatives must be evaluated in terms of societal values and agreed-upon strategic goals. For example, sociopolitical considerations, such as employment, may justify policies to encourage crop production at even very low yields. Many African farmers cultivate land classified as unprofitable for dryland farming, because even low yields bring total production up to a subsistence level.

Land management cannot be effectively integrated without the cooperation of the land users and local communities or the input of decision-makers and political bodies. Evaluation technologies can assist planners and decision-makers as they work with the land users to choose the combinations of land-use alternatives that best meet a specified set of objectives.

Evaluation technologies are essential at numerous points in the land-use planning process. Computer-based analyses and models can be used to evaluate the profitability and environmental sustainability of alternative land-use scenarios. These models can help us identify the critical limiting factors for different land uses, as well as the maximum potential for specific uses. Systems analysis allows us to construct mathematical models of different components of land use: the biological components, such as crop production and forest growth; the physical components, such as hydrologic processes and erosion; and the socioeconomic components, such as households, villages, and national economies. Moreover, systems analysis can help us identify those situations where technological solutions are required and those where socioeconomic interventions are more appropriate.

Monitoring indicators of key processes in land use and economic development is essential for evaluating policy measures. A variety of methods and systems are available to monitor the quantity and quality of natural resources. However, government commitment and investments are needed to guarantee a consistent and unbiased source of both environmental and economic information. The type of measurement used will depend on temporal and spatial scales, the properties of the land, and the objectives of the land users. Indicators for resource use should characterize the rate and direction of change in the processes underlying the functions of the natural resources, reflecting their degradation, depletion, pollution, etc. As much attention should be given to monitoring socioeconomic indicators as is given to monitoring the agroecological ones. The socioeconomic indicators concern changes in production systems (for example, degree of integration of animal husbandry and arable farming); processes like urbanization, industrialization, and resource extraction; income, price, and trade statistics; and so on.

Planning for conservation and agriculture in the United Republic of Tanzania

Efforts to improve land use for agriculture and conservation have a long history in the United Republic of Tanzania. ILM is essential to the future of this country, with its generally infertile soils, difficult climate, concentrated areas of overpopulation, and spectacular natural beauty, wildlife, and biodiversity. In 1976, the World Bank planned a Rural Integrated Development Project for the Tabora region, in western Tanzania. The project included land evaluation, estimation of carrying capacities, and agro-economic studies at the village level to provide the basis for land planning. Tanzania has continued to plan for sustainable development while protecting and enhancing its natural resources, but this is an extremely challenging and difficult task for a poor African nation with pressing social and economic problems. Current efforts to conserve natural resources are supported by Finland (Forestry Action Plan), Sweden (National Conservation Strategy), Denmark (environmental assistance), and Norway (soil conservation and afforestation in the Shinyanga region). Major challenges exist in virtually all areas of technological and infrastructural support for ILM.

Even with adequate monitoring of data and analysis of alternative scenarios, the best combination of land uses may not be obvious. Tools such as IMGP can be used to organize and prioritize socioeconomic and agroecological alternatives. The method is based on the observation that the various interest groups in society have different, at least partially conflicting, objectives. The values attached to goals such as food production, export, employment, and environmental protection are likely to differ for different sectors of society. This method allows all stakeholders to explore the possibilities for a compromise acceptable to everyone, although it may not be ideal for any specific group. The strength of IMGP is its ability to stimulate discussion of the consequences of specific policy options. Nevertheless, such methods alone cannot provide the final solution to land-use issues, which must be resolved on the basis of agreed-upon values and goals.

Atmospheric science allows advanced planning for droughts

Recent advances in atmospheric science offer the promise of long-range predictions of droughts. Strong correlations have recently been reported between the El Niño warming of the Pacific Ocean and severe droughts in Zimbabwe and other parts of Africa (Cane et al. 1994). Because meteorologists are learning how to predict the El Niño warming a year or more in advance, it may soon be possible to predict the growing-season weather in Africa before any crops are planted. The ability to plan for growing-season weather conditions would be a major contribution to agriculture and a totally new component of ILM. Continuing development of such technologies may improve land management and help stabilize food availability in countries such as Zimbabwe and Botswana.

Application sciences and technologies

Application technologies are the on-the-ground methods used to achieve the goals identified during the land-use planning process. The contributions of human innovation and experience, as embodied in many types of indigenous knowledge, have made possible the rapid development and adaptation of methods to improve all aspects of land use. Technologies for specific applications are derived from many different sciences, including agronomy, forestry, hydrology, geology, soil science, wildlife biology, physics, chemistry, mining, and civil engineering.

One of the best-known successes of an application technology is the Green Revolution, which produced high-yielding varieties of cereals that greatly improved food security in parts of the developing world. Researchers in crop breeding and genetics have been developing varieties that tolerate less favourable conditions and require lower inputs than the original Green Revolution varieties. Experimental stations around the world are developing productive crop varieties that are compatible with more effective soil and water conservation. Modern techniques of genetic engineering and more effective use of the genetic resources contained in wild varieties and indigenous crops offer the promise of continued improvement. Animal-breeding programs are providing similar gains in the areas of production and disease resistance. However, these new technologies cannot be effectively applied where they are most needed without better information on soil and climatic conditions in developing countries.

In many cases, the most effective application technologies are hybrids of traditional methods and modern technologies that involve high-efficiency input of resources. The growing body of global experience in land restoration and other aspects of ILM will accelerate the process of solving environmental and development problems in the developing world. Continued testing and refinement of these technologies will lead to further improvements and adaptation to a wider range of environmental conditions.

Land-use planning decreases erosion and increases food production in China

China’s Loess Plateau (530000 km^2) is one of the most severely eroded areas in the world. Beginning in 1979, the Chinese government, in cooperation with the United Nations Development Programme, set up an experimental erosion-control station at Mizhi, in the north of Shaanxi Province. In a 100-km^2 experimental catchment basin shared by three villages, various technologies were evaluated: converting from cultivated annual crops to perennial crops, building additional terraces, controlling gully erosion, and introducing new crop varieties and animal breeds. By the late 1980s, the project had achieved most of its goals. The total land area used for food production was reduced by more than 50%, and stable farmland increased by more than 50%. Forty-seven percent of the total land area is now covered by grassland and forest, which have greatly reduced erosion rates. Total food production increased by 70%, despite the large decrease in cultivated area. This and several similar projects in the Loess Plateau, implemented in collaboration with the World Food Programme and FAO, have demonstrated unequivocally that ILM can simultaneously reduce erosion, increase production, and raise living standards. These methods are now being extended throughout Shaanxi Province and into the Yulin Prefecture (FAO 1992a).

Supporting technologies and infrastructure

An effectively integrated approach to land management needs the support of strong educational, research, and analytical infrastructure. Such infrastructure includes training and extension facilities; analytical laboratories for soil and product analysis, development of product standards, water- and air-quality analysis, and veterinary and medical analysis; and survey methods and databases for land evaluation, cadastral mapping and land registration, and socioeconomic evaluations. ILM projects are unlikely to succeed unless a sufficient in-country expertise is developed to carry out the process and unless sufficient cooperation across traditional institutional and sectoral boundaries is established to make efficient use of the expertise. A strong agricultural extension service can provide critical practical experience and access to indigenous knowledge, as well as the means to communicate the goals and methods of ILM to the land users. Modern analytic and research equipment, as well as computer hardware and software, must be readily enough available to meet the evaluation, research, and monitoring needs of land management.

Because ILM requires the support of all stakeholders and a central authority for implementation, its long-term success depends on having a public that is well enough educated to understand and appreciate the goals of sustainable land management. Both informal and formal education, using all available media, and the legislative and cadastral structures to support long-term economic security are critical to sustainable development.

Support technologies may not be as glamorous or exciting as remote sensing and biotechnology, but they are equally important to the success of ILM. Support technologies can sometimes serve as integrating mechanisms to encourage diverse sectors of society to work together. For example, linked computer networks in which each group is responsible for providing a specific portion of the information every group needs can encourage cooperation between agencies or groups that have not formerly cooperated. Investment in this type of infrastructure provides the foundation for success in ILM.

Chapter 3

Constraints on Integrated Land Management

Numerous barriers impede the effective implementation of ILM at both local and global scales. Some of these barriers can be removed by technology, but many result from the fact that existing technologies are unavailable where they are most needed. Removal of many of the barriers to ILM requires decisions about resource allocation at national and international levels. Barriers to ILM are of four general types:

- Limited access to appropriate information and technology;
- Weaknesses in institutional infrastructure;
- Unsustainable land-use practices; and
- Conflicts between land-use goals.

Owing to variation in environmental and socioeconomic conditions, technologies that are appropriate for ILM in one situation may be inappropriate or unaffordable in the next. The barriers to ILM are also different from region to region and from country to country. Although S&T can contribute to the removal of each of these barriers, the commitment and resources of the political and economic sectors are essential.

Limited access to appropriate information and technology

The starting point for ILM is information on the quality of land resources and their actual land use. This includes information on the following:

- Basic land properties, such as the potential for forestry, agricultural production, mineral extraction, and biodiversity;
- Inherent limitations to the various forms of land;
- Susceptibility to desertification, erosion, groundwater pollution, and other forms of degradation;
- Distribution of land uses and ownership;
- Regulatory constraints; and
- Urban and industrial impacts.

Unfortunately, for many critical land-management situations in the developing world, the needed information either does not exist or is not available in a usable form.

A primary reason for the lack of basic information is the difficulty of obtaining access to the technological tools needed to collect and analyze information. Tools and scientific methods for evaluating the information needed to make land-use and development decisions already exist, but they are not uniformly available in all parts of the world. In some cases, the funds to acquire the technology are insufficient; in other cases, the infrastructural and educational base to support the technology after it is acquired is inadequate. The need for land-use planning tools like remote sensing and IMGP increases with decreasing resource quality; at the same time, the low productivity on marginal lands makes the evaluation technologies and the training needed to use them less affordable.

In some cases, the needed information is available, but it is ignored or neglected. The lack of a timely response to a known problem may be as serious as the lack of early warning of an unknown problem. Frequently, only incidental use is made of the tools available, which results in limited and inadequate land-use planning and management. In such cases, long-term observations on the state of the environment will be scarce. Using indicators of sustainability to monitor the use of resources is essential for assessing the effectiveness of policy measures and the resulting land-use management. Such monitoring must have a strong local component, with measurements and observations done by trained personnel. Advanced technologies, such as remote sensing, will often be useful.

Effective transfer of specific technologies and knowledge from one country to another is hampered by the lack of common methods and definitions for basic land properties, such as soils, climate, land uses, and types of land cover. Standardized definitions for these properties are being developed through a joint United Nations Environment Programme – FAO – Habitat initiative, which should greatly facilitate the implementation of ILM.

S&T cannot solve all the problems. In some cases, the lack of useful information may be related to the imprecision of available S&T. Not all questions about land use and its implications for the environment, the economy, and society will have definitive scientific answers. Available data may be so ambiguous as to hinder an appropriate interpretation or hamper extrapolation of the data to other environments. Moreover, the dynamic interaction between humans and environmental processes is complex and poorly understood. For example, the impacts of human behaviour on the global atmosphere are ambiguous: scientific research predicts consequences ranging from global cooling to global warming and the greenhouse effect. Such information is worthless to decision-makers. In these cases, further scientific research is the only way to improve the decision-making process.

Pakistan's National Conservation Strategy

Growing population, coupled with rapid industrialization and urbanization, was posing a great challenge to optimal resource use in Pakistan. In response, the Government of Pakistan formulated the National Conservation Strategy (NCS) to coordinate public action on issues of resource use. The comprehensive NCS proposes an investment of about US $50 billion over a 10-year period in an action plan to maintain soils in croplands; increase irrigation efficiency; protect catchment areas; support forestry and plantations; restore rangelands; improve livestock; protect water bodies; sustain fisheries; conserve biodiversity; increase energy efficiency; develop and use renewable resources; prevent and abate pollution; manage urban wastes; and support institutions for common resources concerned with land management.

Weaknesses in institutional infrastructure

In recent decades, we have learned a great deal about land use, but the dissemination of this information has not kept pace. The reasons for this include the lack of adequate transfer mechanisms, the limited use of existing mechanisms, and the lack of communication and cooperation between agencies responsible for different aspects of land use. The transfer of information can occur through public-awareness campaigns and education; recovery and use of indigenous knowledge; trained professionals; institutional infrastructure; and mechanisms for local, regional, interagency, and international exchange of knowledge and technologies.

A well-conceived and effectively implemented framework is needed to promote resource management at different levels of society, from the central, regional, and divisional levels to the local (village) planning level. Unfortunately, personnel who have both an environmental education and experience in land-resource management are often lacking at critical levels. In some cases, particularly in the past, insufficient attention has been paid to environmental issues in public education. Extension services sometimes focus on the role of men (neglecting the role of women) in agriculture, household energy, and other environmental aspects. Women's access to education is crucial to the success of development programs aimed at ILM.

Lack of cooperation and communication between agencies may lead to duplication of effort and waste of resources. Inadequate institutional mechanisms for transferring information about market conditions and business opportunities may be as damaging as a lack of information about agricultural technologies. In some cases, technologies have been introduced without emphasizing their drawbacks, such as the toxic side effects of an overuse of biocides.

Without a two-way transfer of information, extension services are unable to create the required link between the farmer's needs and the research findings. Research institutes that concentrate on the well-endowed regions may produce results that have little relevance to the less-endowed regions. A rich fund of indigenous knowledge built up over generations can be quickly lost, reducing opportunities for sustainability. Hybridization of ecologically sound, indigenous farming and modern, high-input agriculture may result in the most efficient use of inputs and create the best chance for economic feasibility, with minimal ecological side effects.

Unsustainable land-use practices

Unsustainable land-use practices include the overexploitation, pollution, and destruction of natural resources. No society intentionally destroys its future well-being or survival by engaging in unsustainable practices. However, economic pressures — as well as simple necessity driven by needs for short-term survival — can lead to the degradation or destruction of the resource base needed for long-term survival and economic well-being. Government pricing structures, subsidies, tax incentives, and trade policies relating to food, wood, energy, and mineral resources may encourage or even force land users to deplete natural resources and thus to undermine their own livelihood. Both national and international economic policies can drive land users toward unsustainable practices.

Scientific knowledge helps preserve biodiversity

Scientific knowledge can help us identify situations in which apparently conflicting land uses are actually compatible. For example, biodiversity conservation is often considered to be in direct conflict with agricultural food production. Yet, recent work indicates that the populations of many components of biodiversity are naturally low on the productive lands that are best suited for agriculture and are actually highest on marginal lands of lower productivity, where the economic value of genetic material for biotechnology may also be high. Thus, using an efficient food-production method, such as mixed cropping, on productive lands and protecting them from degradation can help preserve biodiversity by keeping marginal lands out of intensive agriculture. In addition, this allows the marginal lands to be used for catchment-basin protection, aquifer recharge, water-quality improvement, and tourism.

Land degradation can occur when the land's carrying capacity is reduced by extreme weather, such as droughts, or by overgrazing or erosion. Some regions are much more susceptible to these problems because of their climate, soils, topography, or other factors.

Inequitable distribution of land and other resources can also effectively reduce the carrying capacity of the land — land degradation accelerates when people are forced to use marginal lands. Lack of long-term land tenure or lack of the technology needed to determine and assign land tenure can lead to land degradation by users who have no incentive to improve or conserve resources for the future.

The concentration of population in urban areas has the advantages of increased efficiency and reduced costs for social and physical infrastructure, but the expansion of urban areas also has a direct effect on the adjacent environment:

- Critical thresholds may be exceeded in the environment's self-cleansing potential.
- The water and energy resources may be insufficient to meet the needs of urban development, industrialization, and domestic use. For example, firewood is a common energy source for cooking and heating in most developing countries. The need for firewood in urban areas can easily exceed annual production. An increase in the cost of energy is not the only consequence. Deforestation decreases the buffering capacity of the adjacent environment and leads to erosion and less efficient agriculture, transportation, and industry.
- Deposition of air pollutants from waste incinerators and industrial blast furnaces can lead to harmful concentrations of toxic materials in agricultural products.
- Industrial and urban effluent can make surface water unsuitable for agricultural irrigation.

The carrying capacity of a region is a result of social and economic conditions, in addition to the quantity and quality of the natural resources, so overpopulation is relative. One of the causes of the self-destruction of a society's resource base is overpopulation relative to economic conditions. The situation is particularly difficult if the local or regional soil and climate are too poor to guarantee profitable and sustainable use of external inputs in agriculture and a low supply of qualified labour and other economic conditions hinder the creation of nonagricultural employment, such as in desert margins and semi-arid regions. Large-scale technological investments in these regions are economically unfeasible because of the lack of purchasing power of the local population and the lack of opportunities to increase production. In the long run, however, neglect of marginal regions will threaten the more productive ones because the deterioration or loss of the marginal regions' ecological, social, and economic functions may be critical to the well-being of the more productive regions. Public investment to support sustainable land uses may be the most cost-effective formula for maintaining the functions of ecosystems in marginal regions and avoiding migration and the accompanying social and economic problems.

A long history of land evaluation in Japan

Assessment and improvement of the human-carrying capacity of the land played an important role in the social and economic development of Japan. Careful record-keeping and evaluation of agricultural production during the Tokugawa period allowed Japanese rulers to determine their tax base and regulate the distribution of their rural and urban populations (Sansom 1931; various works of SatÅ¿ [1769–1850], cited in Tsunoda et al. 1958). The fertile soils of the region surrounding present-day Tokyo contributed to the development of an integrated agroeconomic system that supported a high population density and a rich social and economic structure.

Conflicts between land-use goals

Land-use planning is directed to making the best use of land to achieve accepted objectives. However, conflicts inevitably arise between interest groups that have different goals for and perceptions of land use. For example, urban and industrial development often requires land that is extremely valuable for agricultural production. In arid regions, the seasonal movement of livestock usually results in conflicts between herders and farmers of arable lands. Conservationists usually have goals for land management that differ from those of farmers or business people. Many of these goals are interrelated, and obviously they overlap. Where multiple goals are at stake, trade-offs have to be made. Often, no simple technological solutions are available, and societies are forced to make difficult decisions and compromises.

Conservation, development, and management of land resources in India

Because of India's high population density and rich natural and cultural resources, land-use management is of critical concern. In 1991, the National Consultation on the Prospective Plan for Conservation, Development, and Management of Land Resources identified major policy issues and called for an integrated, scientifically sound approach to the management of land resources in the country. A number of initiatives were highlighted:

- Comprehensive land-use planning to govern mining, quarrying, industrial uses, and urban development;
- Coordination of related sectoral policies, such as the National Forest Policy, National Water Policy, National Housing Policy, and National Land Use Policy;

- Higher priority for protective and regeneration aspects of forestry;
- Diversification of agriculture, with special attention to problems of soil salinity, waterlogging, acidity, and drought-prone and desert areas;
- Mitigation of hazards, such as floods and earthquakes, in susceptible areas;
- Proper training of personnel; and
- Continued updating of the information on land resources in India through remote sensing and computerized data banks.

National and regional land-use planning is facilitated by the Agro-Climatic Regional Planning Project of the Indian Planning Commission. The Commission has divided the country into 15 agroclimatic regions for allocation of technical and scientific inputs to the agriculture and allied sectors during the Eighth Five-Year Plan (1992–97) and beyond. S&T will be used in planning, implementing, and managing the programs to address these issues.

The appropriate response to conflicts is not always obvious. For example, high-input agriculture usually attains more efficient ratios of inputs per unit of output than low-input agriculture because production resources are used more efficiently, thanks to a further optimization of the growing conditions. The higher productivity of high-input agriculture also allows farmers to use a smaller area of land to produce the same amount of food as would be produced on a much larger area of low-input agriculture. Thus, a larger area remains available for nature conservation, maintenance of biodiversity, watershed protection, and other socially important land uses. However, owing to the high levels of chemical inputs, local contamination of the environment is much more likely to occur with high-input agriculture. In this context, the complex nature of the trade-offs is particularly obvious: do we employ our nonrenewable resources as efficiently as possible in the well-endowed regions and allow locally high pollution of the environment, or do we use them less efficiently and ensure low pollution of the environment? Such issues cannot be dissociated from the prevailing socioeconomic conditions, which may imply the need for subsidies on external inputs, creation of employment outside agriculture, or income support. Decision-makers need to carefully evaluate all the issues.

Scientific research helps prevent waste of scarce resources

The assessment of agricultural limitations and potential human-carrying capacity is critical in marginal areas, where extreme climatic fluctuations may cause destabilizing swings in agricultural production and human population densities. In Mali, as in the rest of the Sahelian region, periodic droughts cause the collapse of agricultural and grazing systems, with the associated mass migrations and humanitarian crises. The analysis of the limitations that climate and soils impose on the productivity of agricultural and grazing systems indicates that the primary limiting factor is not water but the availability of soil nutrients. Thus, an expensive irrigation project is a waste of money if other limiting factors are not addressed first. An example of using ILM to avoid the waste of resources comes from Ethiopia, where the FAO performed a land-suitability analysis, based on the concept of agroecological zones, for a proposed dam in the Kesem region. Soil analysis showed that soil properties and spatial distributions were incompatible with a successful irrigation project. However, the land evaluation identified areas that would be suitable for various types of rainfed agriculture.

Some kind of public authority — village council, board of public works, development council, or regional or national government — must be involved in negotiating and implementing solutions to land-use conflicts. If they are not, history will repeat itself. In some parts of the world, systems that had been regulating land use efficiently for centuries were weakened during the colonial era. Legislation based on colonial jurisdiction was introduced while indigenous land-tenure systems were still in place, resulting in confusing regulations. Agroecological conditions were neglected, and the land resources deteriorated.

ILM requires choices based on valid and explicit objectives. Because land is multifunctional, these choices inevitably lead to conflicts. However, the lower the availability and quality of natural resources, the higher the risks if decisions are postponed and integrated land-use planning and management are neglected. The destructive processes are accelerated if access to natural resources and external inputs is inequitable or the population as a whole is not involved: irreversible degradation of less-endowed regions will occur and will threaten the functions of the adjacent better-endowed regions.

Chapter 4

Conclusions and Recommendations: Approaches to Technology Transfer and Capacity-building

Some barriers to ILM can be removed with the help of S&T, particularly those problems related to land-management planning and implementation (see “Unsustainable land-use practices” and “Conflicts between land-use goals” in Chapter 3). However, others require socioeconomic solutions, particularly those problems related to the acquisition of appropriate information and technology (see “Limited access to appropriate information and technology” in Chapter 3). Education and infrastructure are themes that cut across all components of ILM (see “Weaknesses in institutional infrastructure” in Chapter 3). Specific barriers related to education and extension, costs, and use of equipment are addressed in other reports (such as UN 1994); nevertheless, these barriers significantly limit the integration of land-use planning and management in many developing countries.

Both the land-use issues themselves and the types of constraints encountered are highly specific to local environmental and socioeconomic conditions. Consequently, it is important that approaches to overcoming these constraints be flexible and adaptable enough to suit a specific country’s or region’s situation.

Experience in both developed and developing countries has shown that a number of approaches can eliminate the constraints on ILM. These approaches can be grouped under the following general headings:

- Intra- and intergovernmental cooperation;
- Private–public partnerships;
- Targeted training and technology-support programs; and
- Direct public investment in resource protection.

Intra- and intergovernmental cooperation

Countries with limited financial resources, infrastructure, trained personnel, and expertise may benefit from pooling resources among themselves to obtain needed information and technologies. As well as being an effective mechanism for sharing solutions to common problems, this cooperative approach may increase the quality and level of information and technology that can be obtained.

However, not all cooperative ventures of this type have been successful. Successful and unsuccessful experiences help us identify the elements important to the success of such cooperative efforts:

- *Common goals and common methods* — It is essential that all cooperators share common goals and that the goals be clearly addressed by the specific information or technology that will be shared by the cooperative. Some top-down efforts by international agencies to provide advanced information from satellite remote sensing were unsuccessful because information was provided in an inappropriate form or was too general and failed to address the specific needs of individual countries. The technology must be sufficiently flexible to provide useful results at many different levels of technological development.
- *Commitment by all partners* — Building a base of trained and experienced personnel with the supporting technical infrastructure requires a serious financial investment and long-term commitment of personnel and institutional support. Potential cooperators must be willing to make a commitment to a sustained effort before being allowed to participate. Programs that do not require commitment rarely succeed.
- *Neutral administrative structure* — Successful cooperation requires that all partners be treated equally and that none dominate the resources or the selection of goals. To avoid any single partner's dominating the cooperative, structures with neutral and independent administration or rotating leadership are essential. Care must also be taken to respect and legally protect the intellectual property rights of participants.

This cooperative networking approach can be used at a number of levels. Small countries that share common resources (for example, catchment basins, mountain ranges) or common problems (such as desertification) can cooperate to achieve an efficient pooling of resources and accomplish what no single country could do alone. Intrasectoral cooperation has also been successful within larger countries (for example, agricultural research stations in different regions, with shared computer systems for accessing satellite data or traditional information sources). Networks are an effective mechanism for pooling and sharing government resources but can also be an effective and cost-efficient structure for donor-supported activities

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International Rice Research Institute: successful cooperation in technology transfer

A program that demonstrates how technology can be effectively developed where it is most needed is the collaborative research guided by the International Rice Research Institute but undertaken by institutes in developed and developing countries, including 16 national agricultural research centres (NARCS) in Asia. The major goal of the program is to improve rice-based production systems through the transfer of modeling and simulation skills. To establish a critical mass within the NARCS, multidisciplinary teams were formed. Hardware and software were donated, and courses on how to use them were organized. The participating institutions were required to make long-term commitments of personnel and support. The common language acquired and the network created permit direct exchange of results, access to common databases, and coordination of ongoing and complementary efforts. The field and laboratory experimentation and the modeling resulted in identification of the key variables and processes needed to improve crop-management systems. Moreover, NARCS can now benefit from the scientific capabilities at international levels.

Experiences in China, India, and the Philippines show that this approach can be easily adapted for use at the national level, enhancing interinstitutional and interdisciplinary work and the integration of knowledge (Penning de Vries et al. 1991). The Agricultural Research Information System being developed by the Indian Council of Agricultural Research and the State Agricultural Universities, with the assistance of the International Service for National Agricultural Research, will be an invaluable tool for international information exchange.

Cooperative arrangements of this type can make important contributions to education, training, infrastructure development, and institution-building. Although most examples of this approach are in the areas of agriculture and natural resources, there is no reason why it could not be used in other areas of sustainable development, such as conflict-resolution methods; manufacturing technologies; energy-efficiency, recycling, and reuse technologies; environmental-geology technologies; and urban and land-use planning methods.

Private–public partnerships

The private sector can make major, mutually beneficial contributions to research and development (R&D) and infrastructure-building in ways that support an integrated approach to land management. The mechanisms by which this can occur are highly varied:

- A banking credit for implementing proven technologies or developing new technologies is a powerful tool for linking sustainable land use with economic development. Successful investment programs based on community lending and women's cooperatives show how capital can be provided to support technology transfer.
- Joint private–public support for R&D institutes to develop new technologies or products or to investigate specific issues of importance to the private sector is already implemented in many developed countries, as well as in some developing countries. This type of private investment goes hand in hand with market development and will tend to increase as markets develop.
- Market development that involves training of technical support staff and provisioning of field offices can contribute to ILM when it also involves appropriate technologies.
- Corporate fellowship programs can build in-country expertise.
- Companies that offer product incentives can help develop markets while making technology available and providing experience and training. For example, with the purchase of a certain product, schools and municipalities might also receive computers or technical training.
- Existing private infrastructure, such as distribution networks for products and product information, can be used to disseminate information related to ILM technologies. Such a network would be particularly important where the channels of public communication are not well developed, such as in rural or mountainous regions, and would benefit field research stations or agricultural extension offices that have difficulties communicating and shipping materials.

Public–private partnerships may prove extremely effective in furthering ILM, particularly as national and international corporations adopt the long-range goals of sustainable development.

Targeted training and technology-support programs

Unsustainable land uses are the most serious threat to sustainable food production on much of the Earth's marginally productive lands. Specifically targeted applications of technology can help remove the primary constraint on planning for sustainable land use — lack of information. Effective integration of land-use planning activities may be extremely difficult at the village level, for example, because of the lack of needed information on surrounding lands, including information on ownership and jurisdictional boundaries; the boundaries of protected or reserved areas; the current conditions of the lands; and the potential future values of the land for agriculture, mining, tourism, catchment-basin protection, and other uses. Land-use planning at the village level can be made more effective by local training programs on data collection and assessment, along with provision of appropriate tools and technology. A small investment in training and technology to support cadastral programs can alter land-use practices by providing the technical infrastructure for secure land tenure.

Conflict-resolution methods, such as the IMGP, can help involve all stakeholders in the resolution of land-use conflicts. Such conflicts arise from differences in private and public interests, values, and influence; lack of local control over land use and land resources; unequal distribution of resources and authority; lack of effective mechanisms for discussing, evaluating, and resolving conflicts; and lack of effective guidance from decision-making bodies. Resolution of land-use conflicts inevitably involves value judgments and subjective or normative evaluations of alternatives. Developing a plan for sustainable land use that is acceptable to all stakeholders and implementing it require strong leadership and the guidance of the right authority. Historically, the failure to resolve these types of conflicts has led to civil strife.

Improved capability for policy review and evaluation by decision-making bodies at all levels is essential in developing an integrated land-use plan for sustainable development. Effective policy evaluation requires accurate information on current land conditions and on the capability of the land to support the future needs of society, including agricultural production, energy sources, mineral resources, clean and abundant water supplies, wildlife and conservation, and recreation and tourism. Providing decision-makers with the training and analytical tools they need for policy review and evaluation would be a major contribution to ILM.

North–South technology transfer in Trieste spawns South–South collaborations around the world

Since 1982 the International Center for Theoretical Physics and the Third World Academy of Sciences, in Trieste, Italy, have been sponsoring courses and workshops in mathematical ecology. Every 2 years, leading scientists from the United States and Europe meet with 50–60 sponsored participants from developing countries for an intensive 3–4 week course on mathematical and computer approaches to issues such as disease epidemiology, water pollution and ecotoxicology, resource management and bioeconomics, and land-use planning. Course graduates are now applying these methods at universities and government institutions around the world. International workshops modeled on these courses have been organized by course graduates and held in Nigeria, Argentina, and Mexico, and more are planned for Asia and throughout the developing world.

Direct public investment in resource protection

Stopping unsustainable land uses before they permanently degrade the land's carrying capacity may require public-sector promotion of sustainable land uses. Deterioration of marginal lands has repercussions for populated regions and productive lands, so governments often make major investments in economically marginal regions. For example, over the centuries, governments in the Netherlands have made massive investments in the dike and canal infrastructure that provides protection to cities and agricultural regions far from the locations where the investments have actually been made. Likewise, the Chinese government has supported extensive tree-planting programs in semi-arid regions to prevent the wind erosion that causes serious problems in major urban areas to the east. Agricultural price supports can help to ensure sufficient input of resources in marginal regions to allow sustainable agricultural practices, rather than continuing land degradation. Such price supports may also be needed to help with the transition from unsustainable agricultural practices to sustainable methods that will eventually become self-supporting. Direct investments in specific land uses to support the economies of marginal regions may often be the most cost-effective solution to the problems caused by unsustainable land uses.

Another type of public investment is the establishment of research institutions to address specific problems of marginal regions, such as issues related to sustainable agriculture, forestry, mining, and the use of other resources. When these institutions are located in the marginal regions as well, they can also contribute to local education and infrastructure development. This type of direct public investment is particularly important in situations where the short-term market solutions that motivate the private sector are inadequate to address land-use problems. In these situations, the central government must have the information and tools for policy evaluation it needs for making decisions that support integrated land use and sustainable development.

Agenda for the future

Despite the availability of S&T solutions to many of the world's land-use problems, most of these problems are, in fact, becoming more serious. Many approaches to land-use management and planning have proven unsuccessful because they had a narrow focus and failed to account for all the factors relevant to sustainable development. PILM therefore emphasizes a holistic and integrated approach to land-use planning and management as the basis for the successful application of S&T.

Both advanced and traditional technologies have an essential role in integrated land-use planning and management. As discussed above, the Panel on Integrated Land Management identified four practical approaches to overcoming constraints on ILM. Each of these approaches can be used to support a variety of programs for technology transfer and technological capacity-building. An ILM program should include the following basic components, each of which requires the application of appropriate technologies to meet specific needs:

- *Information* — Accurate information in a usable form is important to stakeholders at all levels of society (see "Information sciences and technologies" in Chapter 2). For example, television and radio can provide local land users with weather and crop information; satellite data and computer systems can be used to prepare maps and analyses for government planners.
- *Involvement* — The effective participation of all stakeholders, including the poor, women, and minorities, is essential to sustainable land use. For example, communication technologies can foster local, regional, and national dialogues, and interactive evaluation technologies can help develop consensus at all levels of society.
- *Empowerment* — Land users will be committed to sustainable land-use practices only when they can be assured of future benefits. Supporting technologies, such

as navigation satellites that can help in defining land-ownership and land-tenure boundaries, can empower decision-makers at the local level.

- *Facilitation* — The effective implementation of ILM requires a consistent framework of regulations, market structures, and sectoral agencies working cooperatively toward the same goals at regional and national levels. For example, public and professional education is widely recognized as being essential to sustainable development.

Land-management problems, needs, and solutions are specific to each country. The Panel recommends that the principles developed in this report be further elaborated to provide guidelines for implementing technologies that support ILM. The Commission on Sustainable Development (CSD) and the Commission on Science and Technology for Development (CSTD) may consider establishing a joint working group of technology experts and donors to develop general guidelines that cross-sectoral technology-planning groups could use to identify specific technological needs and monitor progress toward ILM. These guidelines would be considered by the CSD and CSTD at their respective sessions in 1997. Once adopted, these guidelines would provide a framework at the national level for facilitating cooperation among sectoral agencies, nongovernmental agencies, and donors that will lead to the efficient allocation and use of technological resources.

Appendix 1

The Panel on Integrated Land Management

Mandate

The Panel on Integrated Land Management was created to provide the Commission on Sustainable Development (CSD) with the information it needs for its deliberation on an "integrated approach to the planning and management of land resources" (chapter 10 of Agenda 21 [UN 1992], adopted at the United Nations Conference on Environment and Development in Rio de Janeiro in 1992). The Panel's task was to address science and technology aspects of land management. Its input was reviewed by the Commission on Science and Technology for Development at its second session (May 1995) before submission to the CSD.

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Appendix 2

Applying Science and Technology in Integrated Land Management

The following are some areas in which science and technology can make immediate contributions to integrated land management. These may provide a basis for successful programing and technical-assistance projects.

- Remote sensing to create the basis for planning and monitoring land use;
- Environmental monitoring;
- Basic geographic information systems;

- Environmental-impact assessments;
- Development and dissemination of superior breeds and varieties;
- By-product reduction and reuse;
- Reclamation and restoration of land;
- Wildlife management;
- Soil management;
- Waste reduction and efficient use of land resources;
- Information exchange through networking;
- Cadastral mapping and land registration;
- Water recycling;
- Systems modeling for water supply, irrigation, etc.;
- Collection, storage, retrieval, and dissemination of information, including market information;
- Disaster prevention;
- Pest-control systems;
- Alternative technologies for energy capture;
- Urban and rural land-use and human-settlement planning; and
- Pollution control.

Appendix 3

Acronyms and Abbreviations

CSD	Commission on Sustainable Development
CSTD	Commission on Science and Technology for Development
DPCSD	Department for Policy Coordination and Sustainable Development
FAO	Food and Agriculture Organization of the United Nations
GIS	geographic information system
ILM	integrated land management
IMGP	Interactive Multiple Goal Programming
NARC	national agricultural research centre
NCS	National Conservation Strategy [Pakistan]
R&D	research and development
S&T	science and technology
UNCTAD	United Nations Conference on Trade and Development

Bibliography

References cited

Beven, K.J.; Moore, I.D., ed. 1993. Terrain analysis and distributed modelling in hydrology. Wiley, New York, NY, USA. 249 pp.

Breman, H. 1987. The struggle of the green against the yellow dragon: the Chinese approach to desertification control and its usefulness for the Sahel. Centre for Agrobiological Research (CABO), Wageningen, Netherlands.

Cane, M.A.; et al. 1994. El Niño warming predicts drought in South Africa. Nature (London), 1994 (21 Jul).

Charreau, C. 1972. Problèmes poses par l'utilisation agricole des sols tropicaux par des cultures annuelles. Agronomie tropicale (France), 27, 905–929.

Drenner, R.W.; Day, D.J.; Basham, S.J.; Smith, J.D.; Jensen, S.I. 1997. Ecological water treatment system for removal of phosphorus and nitrogen from polluted water. Ecological Applications, 7. [In press]

Ellis, J.; Galvin, K.A. 1994. Climate patterns and land-use practices in the dry zones of Africa. BioScience, 44, 340–349.

FAO (Food and Agriculture Organization of the United Nations). 1990a. How good the Earth? Quantifying land resources in developing countries — FAO's agro-ecological zones studies. Land and Water Development Division, FAO, Rome, Italy.

———1992a. China: reclaiming the Loess Plateau. *In* Protect and produce: putting the pieces together. Land and Water Development Division, FAO, Rome, Italy. pp. 14–17.

Fresco, L.O.; Kroonenberg, S.B. 1992. Time and spatial scales in ecological sustainability. Land Use Policy, 9(3), 155–168.

Huston, M. 1994. Biological diversity: the coexistence of species on changing landscapes. Cambridge University Press, Cambridge, UK.

———1995. Saving the planet (and U.S. agriculture) with the 1995 Farm Bill: a farm policy conference (report on a conference). Bulletin of the Ecological Society of America, June 1995.

Hyams, E. 1952. Soil and civilization. Thames and Hudson, London, UK.

Jacobs, J. 1984. Cities and the wealth of nations: principles of economic life. Random House, New York, NY, USA.

Kruseman, G.; Hengsdijk, H.; Ruben, R. 1993. Disentangling the concept of sustainability: conceptual definitions, analytical framework and operational techniques in sustainable land use. Centre for Agrobiological Research – Dienst Landbouwkundig Onderzoek (CABO–DLO), Wageningen, Netherlands. DLV Report No. 2. 61 pp.

O'Loughlin, E.M. 1986. Prediction of surface saturation zones in natural catchments by topographic analysis. Water Resources Research, 22, 794–804.

O'Loughlin, E.M.; Short, D.L.; Dawes, W.R. 1989. Modelling the hydrological response of catchments to land use change. *In* Hydrology and Water Resources Symposium 1989, Christchurch, New Zealand. IAHS Press, International Association of Hydrological Sciences, Wallingford, Oxfordshire, UK. pp. 335–340.

OSTP (Office of Science and Technology Policy). 1994. Technology for a sustainable future: a framework for action. OSTP, Office of the White House, Washington, DC, USA.

Parungo, F.; et al. 1994. Forest plantations reduce dust storms in China. Geophysical Research Letters, 21 (1 Jun).

Penning de Vries, F.W.T.; van Laar, H.H.; Kropff, M.J., ed. 1991. Simulation and systems analysis for rice production (SARP). Pudoc, Wageningen, Netherlands. 269 pp.

Richter, D.D.; Babbar, L.I. 1991. Soil diversity in the tropics. Advances in Ecological Research, 21, 316–389.

Sanchez, P.A. 1976. Properties and management of soils in the tropics. Wiley, New York, NY, USA.

Sansom, G.B. 1931. Japan: a short cultural history. Charles E. Tuttle, Rutland, VT, USA.

SFEIWG (South Florida Ecosystem Interagency Working Group). 1994. Ecosystem restoration and maintenance. Annual Report to the South Florida Ecosystem Restoration Task Force. US National Park Service, Homestead, FL, USA.

Sims, D. 1981. Agroclimatological information, crop requirements, and agricultural zones for Botswana. Government of Botswana, Gaborone, Botswana.

Tsunoda, R.; de Bary, W. T.; Keene, D., ed. 1958. Sources of Japanese tradition. Columbia University Press, New York, NY, USA.

UN (United Nations). 1992. Agenda 21. United Nations, New York, NY, USA.

———1994. Report of the Inter-sessional Ad Hoc Open-ended Working Group on Technology Transfer and Cooperation. Submitted to the Commission on Sustainable Development, 16–27 May 1994, UN, New York, NY, USA.

UNCSTD (United Nations Commission on Science and Technology for Development). 1994. Land management in China: achievements and challenges. United Nations Conference on Trade and Development, Geneva, Switzerland. UNCSTD Country Report.

van Keulen, H.; Wolf, J., ed. 1986. Modeling of agricultural production: weather, soils, and crops. Pudoc, Wageningen, Netherlands.

Vertessy, R.A.; Wilson, C.J. 1990. Predicting erosion hazards using digital terrain analysis. *In* Ziemer, R.R.; O'Loughlin, C.L.; Hamilton, L.S., ed., Research needs and applications to reduce erosion and sedimentation in tropical steeplands. Proceedings of a symposium held at Suva, Fiji, June 1990. IAHS Press, International Association of Hydrological Sciences, Wallingford, Oxfordshire, UK. Publication No. 192. pp. 298–308.

Wolf, J.; Breman, H.; van Keulen, H. 1991. Bio-economic capability of West African drylands. Centre for Agrobiological Research (CABO), Wageningen, Netherlands.

Other reading

Berg, E.J. 1993. Rethinking technical cooperation: reforms for capacity-building in Africa. Regional Bureau for Africa, United Nations Development Programme (UNDP), and Development Alternatives, Inc. UNDP, New York, NY, USA.

Botswana, Government of. 1989. Soils and land suitability for arable farming of South-east District, Botswana. FAO, Rome, Italy. Government of Botswana – Food and Agriculture Organization of the United Nations Project BOT/85/011, Field Document 3.

Breman, H. 1990. Integrating crops and livestock in southern Mali: rural development or environmental degradation? *In* Rabbinge, R. et al., ed., Theoretical production ecology: reflections and prospects. Pudoc, Wageningen, Netherlands. Simulation Monographs, No. 34.

Cathie, J.; Dick, H. 1987. Food security and macroeconomic stabilization: a case study of Botswana. Mohr, Tubingen, Germany.

de Wit, C. T. 1992. Resource use efficiency in agriculture. Agricultural Systems, 40, 125–151.

de Wit, C. T.; Huisman, H.; Rabbinge, R. 1987. Agriculture and its environment: are there other ways? Agricultural Systems, 23, 211–236.

Drenner, R. 1995. An aquaculture system for water treatment. Report to the Tarrant County Water Management District, Fort Worth, TX, USA.

FAO (Food and Agriculture Organization of the United Nations). 1990. Land evaluation for development. Land and Water Development Division, FAO, Rome, Italy.

———1992. Protect and produce: putting the pieces together. Land and Water Development Division, FAO, Rome, Italy.

———1993. Guidelines for land-use planning. FAO, Rome, Italy.

———1994. Towards international classification systems for land use and land cover. A preliminary proposal prepared for the United Nations Environment Programme and FAO. FAO, Rome, Italy.

Harvey, C.; Lewis, S.R., Jr. 1990. Policy choice and development performance in Botswana. Macmillan, London, UK.

Hengsdijk, H.; Kruseman, G. 1993. Operationalizing the DLV Program: an integrated agro-economic and agro-ecological approach to a methodology for analysis of sustainable land use and regional agricultural policy. Centre for Agrobiological Research – Dienst Landbouwkundig Onderzoek (CABO–DLO), Wageningen, Netherlands.

Huston, M. 1993. Biological diversity, soils, and economics. Science, 262, 1676–1680.

Mteleka, T. 1994. Tanzania: case study of the role of science and technology in land management. United Nations Conference on Trade and Development, Geneva, Switzerland, UNCSTD Country Report.

Penning de Vries, F.W.T.; Djiteye, M.A. 1982. La productivité des pâturages saheliens. Pudoc, Wageningen, Netherlands. Agricultural Research Report No. 918. 525 pp.

Penning de Vries, F.W.T.; Jansen, D.M.; ten Berge, H.F.M.; Bakema, A. 1989. Simulation of ecophysiological processes of growth in several annual crops. Pudoc, Wageningen, Netherlands. Simulation Monographs, No. 29.

Pierce, D.; Barbier, E.; Markandya, A., ed. 1990. Sustainable development: economics and environment in the Third World. Edward Elgar, Oxon, UK.

Saveneije, H.; Huisman, H. 1991. Making haste slowly: strengthening local environmental management in agricultural development. KIT Press, Royal Tropical Institute, Amsterdam, Netherlands. Development Oriented Research in Agriculture, No. 2. 239 pp.

Schmidt-Thom, M.; von Hoyer, M.; Lietz, J.; Lorenz, W. 1993. Environmental geology and cooperation with developing countries. Zeitschrift für Angewandte Geologie, 39(1), 1–8.

Siebenhuner, M.; Silitonga, P.H.; Sudradjat, A.; Toloczyki, M. 1993. Environmental geology for landuse and regional planning — greater Bandung area, Indonesia. Federal Institute for Geosciences and Mineral Resources, Hannover, Germany.

UNCSTD (United Nations Commission on Science and Technology for Development). 1994. Some problems caused by inappropriate land management in Latin America and Colombia. United Nations Conference on Trade and Development, Geneva, Switzerland. Country Report.

———1994. Fourteen issues for land use planning. United Nations Conference on Trade and Development, Geneva, Switzerland. UNCSTD Country Report.

van Keulen, H. 1993. Options for agricultural development: a new quantitative approach. *In* Penning de Vries, F.W.T.; Teng, P.; Metselaar, K., ed., Systems approaches for agricultural development. Proceedings of the International Symposium on Systems Approaches for Agricultural Development, Bangkok, Thailand. Pudoc, Wageningen, Netherlands.

van Keulen, H.; Breman, H. 1990. Agricultural development in the West African Sahelian region: a cure against land hunger. Agriculture, Ecosystems and Environment, 32, 177–197.

Veeneklaas, F.R.; Cisse, S.; Gosseye, P.A.; van Duivenbooden N.; van Keulen, H. 1991. Competing for limited resources: the case of the fifth region of Mali. Centre for Agrobiological Research – Dienst Landbouwkundig Onderzoek (CABO–DLO), Wageningen, Netherlands. ESPR Report 4.