CHAPTER 4

ADOPTING AN ECOSYSTEM APPROACH

Adopting an "ecosystem approach" means we evaluate our decisions on land and resource use in terms of how they affect the capacity of ecosystems to sustain life, not only human well-being but also the health and productive potential of plants, animals, and natural systems. Maintaining this capacity becomes our passkey to human and national development, our hope to end poverty, our safeguard for biodiversity, our passage to a sustainable future.

–from the Foreword to this volume

Just as ecosystems sustain us, we must sustain them. We exist with them in a worldwide web—a fraying web of life. The scientific evidence described in Chapter 2 and the practical experience recounted in Chapter 3 underscore the need to weave a different future.

The Pilot Analysis of Global Ecosystems (PAGE) shows that the overall capacity of ecosystems to deliver goods and services is decreasing. Yet human demand for ecosystem products—from water to food to timber—continues to increase. Globally, we have managed agriculture, forests, and freshwater systems to achieve remarkable growth in the output of food and fiber. But when PAGE researchers examined the full range of goods and services produced by five major ecosystems, they found that the increased output of some goods and services has resulted in steep declines

Box 4.1

What Is an Ecosystem Approach?

An ecosystem approach broadly evaluates how people's use of an ecosystem affects its functioning and productivity.

- *An ecosystem approach is an integrated approach.* Currently, we tend to manage ecosystems for one dominant good or service such as fish, timber, or hydropower without fully realizing the tradeoffs we are making. In doing so, we may be sacrificing goods or services more valuable than those we receive—often those goods and services that are not yet valued in the marketplace such as biodiversity and flood control. An ecosystem approach considers the entire range of possible goods and services and attempts to optimize the mix of benefits for a given ecosystem. Its purpose is to make tradeoffs efficient, transparent, and sustainable.

- *An ecosystem approach reorients the boundaries that traditionally have defined our management of ecosystems.* It emphasizes a systemic approach, recognizing that ecosystems function as whole entities and need to be managed as such, not in pieces. Thus it looks beyond traditional jurisdictional boundaries, since ecosystems often cross state and national lines.

- *An ecosystem approach takes the long view.* It respects ecosystem processes at the micro level, but sees them in the larger frame of landscapes and decades, working across a variety of scales and time dimensions.

- *An ecosystem approach includes people.* It integrates social and economic information with environmental information about the ecosystem. It thus explicitly links human needs to the biological capacity of ecosystems to fulfill those needs. Although it is attentive to ecosystem processes and biological thresholds, it acknowledges an appropriate place for human modification of ecosystems.

- *An ecosystem approach maintains the productive potential of ecosystems.* An ecosystem approach is not focused on production alone. It views production of goods and services as the natural product of a healthy ecosystem, not as an end in itself. Within this approach, management is not successful unless it preserves or increases the capacity of an ecosystem to produce the desired benefits in the future.

in virtually all others–from water quality and quantity to biodiversity and carbon storage. In many cases these trade-offs were unconcious. Nonetheless, even with a new awareness of the value of traditionally overlooked ecosystem services like biodiversity or carbon storage, we can't simply reverse the trade-offs we've made. We can't, for example, make do with less food in order to protect biodiversity or improve water quality. The poor and disadvantaged would pay the human consequences of such a strategy.

The case studies in Chapter 3 further underscore our dependence on ecosystems. The villagers who live near Dhani Forest in India have no ready replacement for the food and fiber that Dhani provides, any more than the residents of southern Florida–even with their greater financial means–can find an alternative supply for the plentiful water that the Everglades offers.

Fortunately, the case studies give reasons for optimism. The groundswell of political concern over the deterioration of the Everglades is one sign that awareness of the importance of ecosystems is growing. The community's response to Dhani Forest's degradation assures us that–at least in some places–we are changing our behavior for the better. With its Working for Water Programme, the South African government is simultaneously fighting invasive plants, rising water demand, and poverty. The Programme examines impacts and pressures across ecosystems, challenges political interest groups and perverse economic influences, and forges alliances with the private sector.

Nonetheless, most of the management approaches presented in Chapter 3, as innovative as they are and as difficult as they were to implement, still fall short of a true "ecosystem approach." Some focus only on facets of an ecosystem's health. They include reparative actions, but not always preventive ones. From Mongolia to Bolinao to New York City, none encompasses the broad-scale changes needed to cope with current environmental degradation and inevitable increases in consumption.

What Should We Do to Adopt an Ecosystem Approach?

The principles of the ecosystem approach, described in Box 4.1, are slowly gaining recognition among resource managers. For more than a decade, the concept of ecosystem management has been growing in theory and application. In 1992, the U.S. Forest Service officially adopted an ecosystem orientation to managing U.S. National Forests. Since then, it has struggled to articulate what this means for its timber harvest policies, grazing practices, recreation activities, and management of roadless and wilderness areas. Box 4.2 provides examples of the differences between a traditional approach and an ecosystem approach in forestry.

Box 4.2 Differences Between Traditional Forest Management and an Ecosystem Approach to Forest Management

	Traditional Forest Management	Forest Ecosystem Management
Objectives	■ Maximizes commodity production	■ Maintains the forest ecosystem as an interconnected whole, while allowing for sustainable commodity production
	■ Maximizes net present value	■ Maintains future options
	■ Aims to maintain harvest or use of forest products at levels less than or equal to their growth or renewal	■ Aims to sustain ecosystem productivity over time, with short-term consideration of factors such as forest aesthetics and the social acceptability of harvest practices
Scale	■ Works at the stand level within political or ownership boundaries	■ Works at the ecosystem and landscape level
Role of Science	■ Views forest management as an applied science	■ Views forest management as combining science and social factors
Role of Management	■ Focuses on outputs (goods and services demanded by people), such as timber, recreation, wildlife, and forage	■ Focuses on inputs and processes, such as soil, biological diversity, and ecological processes, since these give rise to goods and services
	■ Strives for management that fits industrial production	■ Strives for management that mimics natural processes and productivity
	■ Considers timber is the most important forest output (timber primacy)	■ Considers all species—plant and animal—important and considers services (protecting watersheds, recreation, etc.) are on an equal footing with goods (timber)
	■ Strives to avoid impending timber famine	■ Strives to avoid biodiversity loss and soil degradation
	■ Views forests as a crop production system	■ Views forests as a natural system, more than the sum of its parts
	■ Values economic efficiency	■ Values cost-effectiveness and social acceptability

Source: Adapted from Bengston 1994

The European Union likewise has begun to frame its environmental problems in terms of large-scale ecosystem effects such as forest loss, widespread nutrient pollution of rivers, and loss of biodiversity. Thus, in its periodic assessments of the environment, the European Environment Agency reports on such indicators as air pollution in excess of ecosystem "critical loads," trends in defoliation of European forest ecosystems, and the effects of fragmentation on Europe's ecosystems (EEA 1999).

At an international level, the ecosystem approach has also gained greater visibility and endorsement. At their biennial meeting in May 2000, the nations that signed the 1992 Convention on Biological Diversity formally spelled out 12 principles that define an ecosystem approach and called for governments to adopt these principles to manage their land, water, and living resources. In their declaration, the nations noted there is no single way to implement the ecosystem approach in all nations, but that the general framework for management must focus on ecosystem processes rather than political jurisdictions and sectoral divisions (COP-5 2000:103–109).

Although these steps toward incorporating an ecosystem approach into land-management decisions represent progress, the wide-scale reorientation of business practices, government policies, and personal consumption habits around an ecosystem approach is still far from reality. In most nations, and in most local practices, the idea of ecosystems as essential biological elements that touch daily life and business remains foreign. At an international level, there is little use of an ecosystem approach when shaping agreements on trade, agriculture, forests, or water use.

Our dominance of Earth's productive systems gives us enormous responsibilities, but great opportunities as well.

Lessons drawn from the PAGE findings and the case studies offer practical guidance for adopting an ecosystem approach. Our recommendations are grouped in four broad areas:

- Tackle the science and information gap.
- Recognize and measure the value of ecosystem services.
- Engage in a public dialogue on goals, policies, and trade-offs.
- Involve all stakeholders in ecosystem management.

These are not a series of sequential steps, but an on-going dance in which we can progress in all areas simultaneously. By following the practical guidance from PAGE and the case studies, we will move more agilely in each area. We already have enough knowledge and experience to get the dance under way.

TACKLE THE SCIENCE AND INFORMATION GAP

Managing ecosystems holistically and sustainably requires a detailed understanding of their function and condition. Without a stronger base of scientific knowledge and indicators at local, national, and global levels, we are ill-prepared to judge ecosystems' productive capacity, to recognize the trade-offs we are making, or to assess the long-term consequences of these trade-offs.

Underlying all of our efforts to tackle the science and information gap is the need for more applicable scientific knowledge. For example, experimental evidence shows that the loss of biological diversity will reduce the resilience of an ecosystem to external perturbations such as storms, pest outbreaks, or climate change. But scientists are not yet able to quantify how much resilience is lost as a result of the loss of biodiversity in a particular site nor even how that loss of resilience might affect the long-term sustainability of the production of goods and services. Better scientific understanding of ecosystems' carrying capacity and thresholds for change would greatly benefit our management efforts.

In some cases, our scientific understanding of ecosystems is improving enough to allow us to build models that will help determine what resources are most at risk and forecast their future. In South Africa, for example, sophisticated computer modeling revealed that allowing invasive trees to spread would severely disrupt water supplies. In the Everglades, modeling of the entire watershed showed just how distorted the water cycle in the region had become. Fifty years earlier, when people were making decisions about altering waterflow in the Everglades, they didn't have such powerful scientific tools at hand.

But more than simply building a better scientific base and honing our understanding of ecology, we must develop and consistently measure indicators of ecosystem extent, condition, and performance. PAGE underscores how sorely our indicators of ecosystem condition are lacking. Often PAGE assessments had to be based on data measured in different periods, governed by inconsistent definitions, or riddled with blanks in coverage. Even for agroecosystems, for which studies of conditions and production abound, there are no globally consistent measurements of the impact of agriculture on water quality and little crop-specific information about the size and production of irrigated areas. In our era of supposed information overload, the PAGE results show that consistent, reliable measures of ecosystem conditions are difficult to ascertain both on a global scale and on a local or national scale where most land use decisions are made.

The case studies, too, clearly illustrate the need for improved indicators, consistent monitoring, and reporting on ecosystem condition. The longer cases chronicle the gradual transformation of ecosystems through physical alteration or overuse, a period when individuals and institutions sometimes failed to recognize early warnings of ecosystem decline or were unable to assess the long-term repercussions of their choices. Part of the challenge is that ecosystem decline may begin gradually, then manifest quickly as pressures increase. Florida Bay degraded slowly in the first two decades after the Central and South

(continues on p. 232)

Box 4.3 The Need for Integrated Ecosystem Assessments

How can we judge whether an ecosystem is in good condition? Scientists have taken several approaches:

- *Measuring against natural systems.* Some scientists have suggested that the condition of an ecosystem could be measured by comparing one or more of an ecosystem's properties (such as biomass, number of species, or the flow of nutrients through the ecosystem) to those of a "natural" or "undisturbed" ecosystem. This would effectively define the condition of an ecosystem to be its degree of "non-naturalness." But the shortcomings of this approach for policy and management decisions are clear. Judging condition with such an indicator of "naturalness" would mean, for example, that all agroecosystems or forest plantations would be defined as being in poor condition since they are quite different from the natural ecosystems that they replaced. Moreover, given the pervasive influence of human action on the global environment, it is increasingly difficult to define what a "natural" or "undisturbed" ecosystem would be like.

- *Measuring sectoral conditions*. Many reports have been written about the state of agriculture in various countries focusing only on food production, without considering the potential negative effects of that food production on biodiversity, water quality, or carbon sequestration. Or forest assessments have examined only timber production, without evaluating the potential impact of timber harvest on regional rainfall, energy production from downstream hydro-facilities, or biodiversity loss. This strictly sectoral approach made sense when trade-offs among goods and services were modest or unimportant. But it is insufficient today, when ecosystem management must meet conflicting goals and take into account the linkages among environmental problems. A nation can increase food supply by converting a forest to agriculture, but in so doing decreases the supply of goods that may be of equal or greater importance such as clean water, timber, biodiversity, or flood control. Both local resource managers and national policy makers need some means of weighing these trade-offs, which requires a more integrated view of just what those trade-offs might entail.

- *Measuring for optimization.* An integrated assessment determines the condition of an ecosystem by assessing separately the capacity of the system to provide each of the various goods and services and then evaluating the trade-offs among those goods and services. Even if the trade-offs are conscious choices, an integrated assessment will show whether the capacity of the system to provide a *combination* of the services is optimized. For example, in an acceptably productive agroecosystem that relies on chemical inputs, separate assessments could show whether the addition of a rotation of a green manure crop could greatly reduce nutrient inputs, dramatically increase water quality, or affect agricultural yield. Thus, it could be determined whether the ecosystem was being managed to optimize the provision of a combination of food and clean water or whether these goods might have been achieved through an alternative management approach.

This approach to ecosystem assessments is called an "integrated assessment" because it examines not just a single ecosystem product, such as crop production, but an entire array of products that the ecosystem might provide. The principal benefit of an integrated ecosystem assessment is that it provides a framework for examining the linkages and trade-offs among various goods and services. The opportunity to increase the aggregate benefits from the bundle of goods and services produced by an ecosystem would be hidden in an assessment of each sector in isolation. The goal of management of the ecosystem may well be to favor one service, say, food production, over the others, but by looking at the production and condition of the entire array of services, trade-offs among various services become apparent.

Box 4.4 Using Information to Support an Ecosystem Approach

In collaborating on this report and supporting a global assessment of ecosystems, the United Nations Development Programme, the United Nations Environment Programme, the World Bank, and the World Resources Institute confirm their commitment to use information to motivate actions that will maintain and restore ecosystems. Governments, businesses, organizations, and individuals everywhere have many opportunities to match that commitment:

- Governments can use their access to information to drive decisions on ecosystem use, protection, and restoration. Government agencies and officials now have more and better data than ever before, through advancements in science and technology, and they are in the best position to integrate satellite habitat imagery, air and water quality readings, biological data, demographic information, and transportation and land-use maps. For example, government regulators can incorporate scientific findings on ecosystem thresholds, such as the "critical load" of pollutants like SO_x and NO_x, in regulations that govern automobile and powerplant emissions or water quality standards.

- Businesses can improve their environmental performance in relation to ecosystems by collecting and disseminating information about the environmental aspects of their processes, products, and services. Although government regulations are powerful means of requiring businesses to manage and report on their performance, increasing numbers of businesses around the world are voluntarily adopting environmental management systems and publicly disclosing information on their performance. Many businesses do so to save money, to increase shareholder value, to benchmark their performance, and to monitor their compliance with external commitments.

- Industry associations can develop policies and codes that respect the need to keep ecosystems viable. One model for how such ecosystem-friendly business practices can be promulgated is the International Organization for Standardization's ISO 14000 standards, which provide guidance to companies that want to improve their environmental management in a number of areas, including environmental auditing, labeling, and product life-cycle assessment. As of July 2000, 14,106 companies in 84 countries have adopted the ISO 14000 standards. Another model is the Global Reporting Initiative (GRI), which was established in 1997 by the Coalition for Environmentally Responsible Economies and the UN Environment Programme, with the mission of designing globally applicable guidelines for preparing enterprise-level sustainability reports. The GRI guidelines are available online at http://www.globalreporting.org.

- Universities, environmental groups, and civic associations can help interpret the wealth of raw data that is already available—presenting data in user-friendly, indexed, nontechnical formats that allow anyone to navigate lots of information quickly. Such organizations can compile risk-ranked lists of facilities or production methods, integrate data sets, or create rankings of popular consumer products based on the presence of suspected toxins, for example. They can also "watchdog" ecosystem management, ensuring that we truly take an ecosystem approach by promoting open planning processes, organizing and informing constituents, and demanding accountability from governments, multilateral banks, and corporations.

- Consumers can seek product information and use purchasing power to drive businesses to better practices on behalf of ecosystems. Certification of sustainable management practices or "ecolabeling" already enables us to choose the timber, agricultural products, and fish products that are produced and harvested with the fewest ecological impacts. For example, the Forest Stewardship Council assesses forest management practices against a set of 10 environmental, social, and economic principles and has certified more than 15.8 Mha of productive forestland worldwide (Parker et al. 1999:12). Business leaders such as IKEA, the largest furniture manufacturer worldwide, are turning to those forest products both to gain a marketing advantage and to respond to consumer interest in more environmentally sensitive products. Similar certification processes, such as Energy Star ratings, are already in place to help consumers evaluate the energy consumption of appliances, and others could be developed for environmentally sensitive goods and services, such as community-based lodging and guides for ecotourism.

- Citizens everywhere can make a point of learning more about the environmental conditions and issues in their surroundings. Those with access to the Internet can readily get information to help them make decisions about voting, using local land and resources, recycling, and disposing of household wastes, for example. They also gain the means to share the information with friends and colleagues, or voice their opinions—sometimes just by sending a message with another click on the keyboard.

Florida Project altered the Everglades water flow, then rapidly in the last decade. In South Africa, the connection between imported plants and water supply took almost a century to identify with certainty. The years that it took to recognize the damage and change course amplified the repercussions of degradation–both on the ecosystem and on those dependent on the goods and services that had been compromised.

Not all information is equal, however, when it comes to supporting an ecosystem approach. Integrated assessments are the most effective means to encourage stakeholders to manage ecosystems for more than their immediate commercial value(Box 4.3 The Need for Integrated Assessments). Such assessments separately determine the capacity of an ecosystem to provide various goods and services and then evaluate the trade-offs among those goods and services. Narrower sectoral measures, which have been the principal sources for most decision making, focus on a single outcome, rather than consequences across the ecosystem. Thus, the government agencies that replumbed the Everglades judged their success on the basis of agricultural production and flood control. The agencies that forested South African mountains with pines had their sights set on maximum timber output, as did the government in Dhani, which permitted commercial contractors to harvest the forest canopy. Only at crisis points–when the supply of critical goods like food or water was interrupted–did serious interest develop in analyzing other indicators of the health of these ecosystems. Perhaps the crises would never have occurred if more integrated information had been available at the outset.

Of course, that's a wishful thought. No matter how sophisticated our scientific understanding, computer models, and original statistics, we are still likely to be surprised by ecosystem outcomes unless we monitor them continuously. Just as our knowledge of ecosystem dynamics is rapidly changing, so is the scale of pressures–demographic, economic, and biological–that will alter ecosystems. Periodically assessing ecosystems is key to avoiding unexpected outcomes. In Bolinao, only years of monitoring a variety of environmental indicators will show whether the new four-zone coastal management plan is helping fish stocks rejuvenate, or whether other factors outside the purview of the plan are more critical. The New Yorkers who drink unfiltered water must rely on extensive water quality monitoring to determine whether their ecosystem protection plan is adequate or whether an investment of billions of dollars in a filtration plant is necessary. A careful record of monitoring may verify suspicions that new ecosystem management is needed–and can help the largest and most expensive efforts, like the Everglades restoration plan, withstand inevitable public and legal challenges.

Sound scientific analysis, modeling, assessment, and monitoring can increase the wisdom of ecosystem management decisions. The scope of action for tackling the science and information gap is large indeed, and it spans governments, businesses, organizations, and individuals (Box 4.4. Using Information to Support an Ecosystem Approach). But it is not the only requirement for an ecosystem approach.

RECOGNIZE AND MEASURE THE VALUE OF ECOSYSTEM SERVICES

Undervaluing ecosystem services has contributed to many shortsighted management practices. The PAGE study of freshwater systems, for example, argues that heavily subsidized water prices, especially for agriculture, have promoted the inefficient use of water. The study documents the sixfold increase in water consumption since 1900 worldwide, more than twice the rate of population growth. The PAGE study of forest ecosystems shows that old-growth forests in Canada–where logging companies' operations are subsidized–are harvested far in excess of their rate of growth, despite the forests' value in terms of biodiversity, carbon storage, and watershed protection. Market mechanisms have generally failed to assign monetary values to such public goods, but market failure is not solely responsible for the exploitation of ecosystem services. Tax breaks, trade incentives, tariffs, public-investment strategies, and other economic policies have distorted the price of water, land, and other ecosystem inputs and outputs.

The case studies, too, provide a wealth of examples of economic policies that, despite good intentions, have aggravated declines in ecosystem condition and capacity by undervaluing essential ecosystem services. For example, government funds subsidized the drainage of nearly one-fourth of the Everglades south of Lake Okeechobee to create the Everglades Agricultural Area. In addition to the direct damage this drainage inflicted on wildlife habitats, it also set the stage for indirect injury to the Everglades through water withdrawals, polluted runoff, and soil subsidence from agricultural production.

An essential element of an ecosystem approach is recognizing and measuring the value of ecosystem services, so that governments, industries, and communities can factor these values into their production and consumption choices. A first step toward setting these values is calculating the cost of economic policies that subsidize the use of resources, either by comparing subsidized to market prices or by summing the cost of government subsidy programs. Worldwide, subsidies supporting environmentally unsound practices in the use of water, agriculture, energy, and road transport are estimated to total US$700 billion, with almost half that amount supporting farm production and farm income in OECD countries (UNEP 1999:207). Refining and disaggregating this amount into national, local, or sectoral components is feasible and, even if imprecise, would provide some empirical basis for adjusting distorted prices. Going further to remove subsidies and set explicit prices on ecosystem services may be politically difficult but would lead directly to more efficient resource use.

South Africa's water law is an example of explicit pricing to encourage efficiency(see Box 3.14, pp. 200–201). South Africa allows the Department of Water Affairs and Forestry to

We can do better at managing ecosystems than we have in the past, and we can do better *today*.

levy watershed management charges on those sectors that use rivers and other water bodies for waste disposal and water consumption. Those fees are expected to discourage waste, promote conservation, and provide funds to improve watershed health. Some sectors and communities have resisted new water charges, but others have instituted municipal conservation practices that reduced water use by 25 percent.

For ecosystem services that are not explicitly subsidized, other methods of valuation need to be developed or improved (see Box 1.14, p. 32). Environmental economists should continue to hone our abilities to guage the value of ecosystem goods and services, and such values should be transmitted to those making decisions on landuse and industrial production methods. An example of how such valuation can be brought into more common use is the Environmental Valuation Reference Inventory, compiled by Environment Canada. This database of valuation studies allows corporations and government agencies to quickly call upon accepted research on monetary values for a variety of environmental services. These values, in turn, can be used to estimate the effects of projects or developments that may degrade these services (EVRI 2000).

Ultimately, creating financial incentives for ecosystem conservation is more important than setting an accurate price on ecosystem services. The price of many ecosystem services may prove to be incalculable from any supply-and-demand equation. Nonetheless, we should not lose sight of the fact that subjective judgment is at work in every valuation. The aesthetic appreciation or spiritual significance of a given landscape depends on the values of the beholders, just as the price of a particular good depends on the buyers' willingness to pay. In a debate that has focused on scientific and economic measures of value, community and religious leaders have a unique opportunity to raise the ethical considerations that should guide our use of ecosystems. Thus the valuation of ecosystem services–like the ecosystem approach as a whole–is most effective when it engages a public dialogue on goals, policies, and trade-offs.

ENGAGE IN A PUBLIC DIALOGUE ON GOALS, POLICIES, AND TRADE-OFFS

With an ecosystem approach, knowledge of ecosystem processes and conditions serves as the foundation for public discourse on what we want and need from ecosystems, how the benefits should be distributed, what the ecosystems can tolerate in terms of degradation, and what we can tolerate in terms of costs. The discourse is itself a foundation for concensus about what actions need to be taken. Even a tenuous consensus among competing interests in the New York watershed or the Bolinao reefs or the Everglades wetlands is a powerful facilitator of change, often more powerful that any engineer's technology, government's mandate, or consultant's report.

The story of New York City's watershed management plan is an example of an effort to bring together all those who have a stake in the health of an ecosystem and identify a common theme around which they could unite–in this case, water. Although the negotiated outcome in cases like New York City may not be ideal from a scientific perspective (the protection plan has been criticized as inadequate), it represents progress over interminable wrangling or inaction. Plus, when all interest groups are part of the solution, the results are usually more sustainable than those achieved without broad stakeholder participation.

When governments fail to broaden the dialogue on ecosystem management to include all stakeholders, nongovernmental organizations with ties to the local community can be powerful agents of change. The value of NGOs stands out in stories like the restoration of the Mankòtè mangrove and coastal management in Bolinao. There, NGOs persisted with countless consultations to forge alliances among the stakeholders and to elicit wider participation in decision making.

Many public dialogues on resource use are not only about the present–the relocation of a levee in the Everglades or the area for work crews to fight invasives in South Africa–they are implicitly about the future. Discussions about the best course

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Box 4.5 Filling the Information Gap

Ecosystem	Characteristic	Principal Information Needs
All ecosystems 	Extent and land use	Satellite imagery has improved knowledge of the extent of various ecosystems, but available data are rarely precise enough to use at the national or subnational levels or to support all the needs of international environmental conventions. More frequent interpretations, improved data resolution, more systematic classification processes, and innovative approaches to ground-truthing are needed.
	Soil degradation	The only comprehensive global source of information on soil degradation (GLASOD) was undertaken in the late 1980s; a supplemental study, using more detailed information, only covered Asia (ASSOD). Needs include longer-term monitoring of soil organic matter, more detailed data on soil nutrient balances, and more work on indicators that show the link between soil quality and ecosystem goods and services.
	Biodiversity	Information on biodiversity is poor across ecosystems. Only an estimated 15-20 percent of species have been identified, although the Global Taxonomy Initiative is trying to address this issue. Even for known species, information on population trends and invasions is lacking. The Global Invasive Species Programme and the World Conservation Union are assembling databases on invasives, and considerable data exist among scientists, museums, or plant collections in all countries, but effort is needed to assemble them into a form that can inform national planning.
	Water quantity and quality	Better information on water resources can immediately benefit nations because of its direct link to human health and well-being. In most parts of the world (except OECD countries), water quality monitoring is rudimentary, and most efforts leave out important biological information. Groundwater data are not readily available at a global or continental scale.
Agroecosystems 	Condition	Food production and yield statistics are copious, but less is recorded about the underlying condition of agricultural systems, much less about differences in farming systems and land management practices. Reasonably detailed land use data are needed to predict the impact of agriculture on soil fertility, water quality, and habitats. Current data on soil degradation, water quality, and biodiversity are qualitative and often controversial.

Ecosystem	Characteristic	Principal Information Needs
Coastal Ecosystems 	Biodiversity	Availability of global biodiversity data for coasts and oceans remains limited; even data on the distribution of habitat types are lacking for most areas, except for coral reefs and mangroves. Because most coastal habitats are small and submerged, local surveys, such as the Global Coral Reef Monitoring Network, are still more reliable than remote sensing in determining extent and condition.
	Fisheries	Outside of North Atlantic fisheries, only 50-70 percent of landings are now reported by species, which precludes efforts to evaluate the impact of fishing on specific species. Population information on fish stocks, which is needed to assess whether harvests exceed sustainable levels, is still more fragmentary.
	Water quality	Remote sensing can help to fill information gaps about occurrence and duration of algal blooms, oil spills, turbidity, and sea surface temperature, but on-site monitoring is needed to evaluate many coastal water quality parameters, such as eutrophication, coliform bacteria, and persistent organic pollutants, as well as to monitor disease outbreaks among marine organisms. The Global Ocean Observing System established by the United Nations could compile such data.
Forest Ecosystems 	Condition	Extraordinarily poor data on woodfuel production and consumption will be difficult to supplement, since monitoring will be costly in most developing countries. Key data needs related to timber production are the relative rates of growth and harvest in production forests. Improved deforestation estimates will require both better satellite coverage and corroboration on the ground.
Freshwater Ecosystems 	Water quantity	Rain and stream gauges around the world are disappearing, victims of loss of funding for monitoring programs. Better basic hydrological information about river discharge, flood frequency, dry season flows, condition of wetlands, and location of dams would help planners meet the growing human demand for water.
	Fisheries	Improved data on inland fisheries, essential to ensure their sustainability, will require improved or new monitoring networks, since much of the catch is consumed locally and unrecorded.
Grassland Ecosystems 	Condition	High resolution satellite data measuring the productivity of grasslands, combined with on-the-ground measures of rainfall, livestock densities, and management systems could greatly increase our understanding of desertification and help national governments better manage rangelands.

of growth in a crowded area or about the rationale for allocating scarce resources or even about the nature of sustainability itself can mold a common sense of value among diverse participants. Thus, public dialogue can help the community make judgments about the relative importance of different ecosystem services. The dialogue also promotes public awareness and education; it encourages participants to learn more about the social, economic, and physical trends that are likely to affect their best-laid plans in the future.

Thus, it is essential that the stakeholders now trying to ensure the viability of ecosystems–like the Mekong River Basin or Bolinao's coastal resources–strive to incorporate projected future social and ecological changes. In the Mekong, the extraordinary pace of economic and population growth will inexorably drive intertwined demands for irrigation, drinking water, hydropower, fish production, salinity control, and transport. Bolinao's new coastal management plan may suffice for the municipalities' current population of 50,000, but the area's long-term health will depend in part on the plan's ability to incorporate a potential doubling of the population in 30 years (McManus et al. 1995:195).

Governance systems that encourage community decision making create powerful incentives for local conservation. But local solutions may not always be sufficient to keep up with rapidly accelerating, rapidly changing stresses. In those circumstances, more enduring efforts have to involve the widest possible range of stakeholders not only in dialogue but in implementation.

INVOLVE ALL STAKEHOLDERS IN MANAGING ECOSYSTEMS

Local communities can be the most pernicious violators or the most prudent managers of ecosystems. Often motivated by poverty or short-term gains, they have the greatest opportunity to overuse ecosystem goods and services. At the same time, their knowledge of their ecosystem and their direct stake in its health are important assets that improve the chances for long-term stewardship.

Similarly, national agencies, multinational businesses, and international organizations have all demonstrated their powers of destruction, as well as capacities for broad vision and enlightened policies on the use of ecosystems. National or multinational goals may conflict with–and dominate–local ones, as they did in Dhani during the period of greatest local degradation. But the growing environmental sensitivity of internationally financed demonstration projects, such as some of the best ones undertaken by the World Bank and the United Nations, can encourage local and national interests to adopt an ecosystem approach.

Involving all essential local, national, and even international interests in ecosystem management thus produces better outcomes. Inclusion of all stakeholders brings more knowledge and experience to bear on problems. The process of inclusion can balance interests that may be legitimate but divergent and can yield a more equitable distribution of the benefits and costs of ecosystem use.

Local stakeholders, however, often have the most to gain or lose in managing ecosystems. Dhani provides the quintessential example of how community concern and action can revive a local ecosystem. Driven by their dependence on the forest and their understanding of how it had been degraded, the villagers of Dhani forest crafted an effective forest protection plan. When the state, which owns the forest land, later blessed the plan, it made the local community partners in the restoration rather than adversaries. Likewise, in Machakos, the demise of government-instigated compulsory work groups in the 1950s enabled the Akamba to return to the traditional clan-based *mwethya* and to undertake–on their own initiative–the conservation techniques and work styles that rejuventated their agroecosystems.

The case studies also underscore how local communities with secure rights of resource use tend to manage ecosystems more sustainably. By contrast, consider how Dhani residents abandoned carefully crafted rules of forest access and use in favor of hastened harvesting of fuelwood when state and commercial cutting in the 1960s–70s undermined their tenure. Similarly, pastoralists in Mongolia who are uncertain about their rights to common property grasslands are less likely to use the sustainable practice of pasture rotation, for fear of losing access to lands to another herder and his flocks.

Sadly, ecosystem mismanagement continues as a result of government policies that displace local people, exploit natural resources for quick capital, and fail to recognize the role that ecosystems play in the development of sustainable livelihoods, especially for the poor. Tenure remains in question for millions of people, even as experience has repeatedly shown that secure tenure and the authority to manage resources promote long-term investments in land improvements and careful stewardship.

What Does the Future Hold?

The case studies suggest that people do learn and adapt and that ecosystems do have some natural resilience. But they also warn that there are limits to how much an ecosystem can recover. It is possible for a forest that has lost biomass and habitat quality, like Dhani Forest, to rebound in just a few years once overuse is controlled. It is less likely that wetlands, as in Florida, can be restored to health in areas already converted to suburbs, roads, and malls. Meanwhile, restoration will demand expensive financial investments in places like South Africa and Florida, and significant human capital in places like Dhani, Machakos, and Cuba–outlays that depend on strong public and governmental will.

Box 4.6 The Call for a Millennium Ecosystem Assessment

It is impossible to devise effective environmental policy unless it is based on sound scientific information. While major advances in data collection have been made in many areas, large gaps in our knowledge remain. In particular, there has never been a comprehensive global assessment of the world's major ecosystems. The planned Millennium Ecosystem Assessment, a major international collaborative effort to map the health of our planet, is a response to this need. It is supported by many governments, as well as UNEP, UNDP, FAO and UNESCO. I call on Member States to help provide the necessary financial support for the Millennium Ecosystem Assessment and to become actively engaged in it.

— UN Secretary General Kofi A. Annan
From *We the Peoples: The Role of the United Nations in the 21st Century* (April 2000)

Also endorsing the Millennium Ecosystem Assessment as of September 2000:

- Conference of parties to the Convention to Combat Desertification
- Conference of parties to the Convention on Biological Diversity
- Conference of parties to the Ramsar Convention on Wetlands
- Consultative Group on International Agricultural Research and the International Agricultural Research Centers
- Millennium Assessment Steering Committee, representing 30 international agencies and research
- Ministers of the Environment meeting in Elmina, Ghana, September 1999, representing 20 countries
- Third World Academy of Sciences
- Third World Network of Scientific Organizations
- *World Resources* partners UNDP, UNEP, World Bank, and WRI

The case studies do not end here. Only time will reveal the level of health that any of these degraded ecosystems regain. We know the "restored" Everglades system will be different in species composition and functioning than the original system. South Africa will never entirely be rid of its invading plants, despite the best efforts of the Working for Water Programme.

Climate change, globalization, and urbanization are pressures that could undermine the long-term successes of even the most informed, carefully constructed management and restoration plans. Increasing global carbon emissions are already affecting ecosystems. Warmer temperatures and changes in rainfall patterns could encourage migrations and invasions of nonnative species, and rising sea levels could submerge many low-lying areas, from coral atolls to parts of the Everglades ecosystem. Globalization and industrialization are likely to destabilize many traditional economic patterns that focus on subsistence and local resource use. Suburban sprawl, habitat fragmentation, air pollution, and the sheer scale of resource demand and waste generation will take a toll before better urban planning begins to minimize these stresses.

Successful ecosystem management will increasingly require the cooperation of neighbors–sometimes people with widely divergent goals. Dhani residents had only to work with adjacent villages, but South Africa must work with Botswana and Zimbabwe to control dense infestations of nonnative plants like rose cactus, the distribution of which is accelerated by elephants and donkeys moving freely across borders. Even that is a relatively local problem compared with the transboundary issues raised by efforts to develop and manage the Mekong River sustainably. There, the wishes and needs of six nations all threaten the quantity and quality of the water in the Basin, and the livelihoods of the fishers and farmers in the Lower Mekong.

The international agreement to stem stratospheric ozone depletion (the Montreal Protocol) suggests that we can–aided by sound science–formulate a shared vision and commitment to manage a problem, once we understand its severity. But for some ecosystem services, like biodiversity and carbon storage, a shared understanding of their importance may not be enough to bring about cooperative global management. International markets do not value ecosystem services, such as biodiversity or carbon storage, as the public assets they are. Yet they are essential assets of global importance; thus, the global community may need to bear some of the costs of sustaining them. International efforts to supply public capital and leverage private-sector

investment will be a crucial factor in changing how countries value and conserve their ecosystems.

Perhaps the most important message in the case studies is that we can do better at managing ecosystems than we have in the past, and we can do better today. We often tout technology's promise of solving problems: making restoration cheaper or increasing the productivity of our ecosystems. These cases don't undermine technology's promise, but they remind us that we already have much of the knowledge and technology we need. Many of these "fixes" are simple and nontechnical. In South Africa, people are restoring the ecosystem by uprooting invasive trees by hand. In Dhani, a community employs watchmen and patrols, uses simple harvest plans and bans cattle grazing, and promotes alternative local employment. In Machakos, the Akamba collect rainwater and construct terraces–a practice dating back to ancient times in many parts of the world.

Put simply, we already know enough to begin to manage ecosystems more soundly and to restore some of the natural productivity we have lost. Mustering the local, national, and global commitment to use and expand that knowledge is the challenge.

A Millennium Ecosystem Assessment

Our failure to think in terms of ecosystems has been rooted in the profound lack of information about how ecosystems affect us and what condition they are in. The Pilot Analysis of Global Ecosystems begins to address this information issue. But one of the most important conclusions of the PAGE study is that we currently lack much of the baseline knowledge we need to assess ecosystem conditions adequately on a global, regional, or sometimes even a local scale. PAGE researchers noted the absence of dozens of critical data sets–from the level of fuelwood use to the impacts of livestock on grassland forage conditions (Box 4.5 Filling the Information Gap).

Considering our technological advances, it is surprising that the availability of information for assessing the condition of ecosystems has not improved in recent years and may actually be decreasing. On the one hand, remote sensing has made information available about certain features of ecosystems, such as their extent. On the other hand, on-the-ground information for such indicators as freshwater quality and river discharge is less available today than 20 years ago (Stokstad 1999:1199).

Gathering this kind of information and making it available in a form that governments, businesses, and local residents can easily understand and use will require a much larger, more comprehensive effort than PAGE. Such an effort, the Millennium Ecosystem Assessment (MEA), scheduled to begin in 2001, is organized and supported by an array of governments, UN agencies, and leading scientific organizations (Box 4.6 The Call for a Millennium Ecosystem Assessment). The PAGE study itself provided a demonstration of some of the methods and approaches the MEA will use, but the MEA will develop and expand these methods for global application by a diverse group of researchers acting at several scales, from local to global.

The MEA, like the PAGE study, will focus on the capacity of ecosystems to provide goods and services important to human development. Thus, it will consider the underlying ecosystem processes on which these goods and services depend. Furthermore, it will explicitly consider social and economic attributes such as employment and economic value. The MEA will consist of a global assessment more comprehensive than the PAGE study and approximately 10 assessments undertaken at regional, national, and local scales. It will also help nations develop more capacity to do their own assessments in the future:

- *The global component of the MEA* will establish a baseline for future assessments, help meet information needs of the international environmental treaties, like the Convention on Biological Diversity, establish methodologies for integrated ecosystem assessments, and raise public awareness about the importance of ecosystem goods and services. The global component will be uniquely suited to assessing change in global chemical cycles of carbon, nitrogen, and water.

- *The regional, national, and local components of the MEA* will cover only a small portion of the globe but will help to catalyze more widespread use of integrated assessments and help to develop the methodologies and modeling tools needed for those assessments. These components will also provide information that bears directly on management and policy decisions in the regions where they are conducted, and they will be uniquely suited to assessing tradeoffs and linkages among various goods and services. The development of scenarios describing plausible future conditions of ecosystem goods and services will also take place at a regional level and be synthesized at the global level.

- *Capacity building* will also be a central objective of the MEA process. The regional, national, and local components of the MEA will directly strengthen the institutions involved. The information, methodologies, and modeling tools developed through the MEA will be of use to national and subnational assessment processes around the world. Finally, the MEA will help to promote the data collection and monitoring efforts needed to meet information needs at all scales.

The MEA is just one of many steps necessary to reorient our view of ecosystems and how to manage them. Yet it is one of the first and most elemental. If the MEA is successful, it could provide a foundation of knowledge about ecosystems that would offer immediate utility and guidance for policy makers tackling such basic issues as water use, coastal development, agricultural policies, and biodiversity conservation. At a more fundamental level, it would mark an important step toward an ecosystem approach by beginning to frame the environmental information that decision makers use in terms of ecosystem goods and services. In time, this basic reorganization of how we measure and analyze environmental change will embed the concept of ecosystems into how we talk about and manage our impacts on the Earth.

What Better Time Than Now?

Our dominance of Earth's productive systems gives us enormous responsibilities, but great opportunities as well. Human demands on ecosystems have never been higher, and yet these demands are likely to increase dramatically, especially in developing countries, as rising populations mean more and more people are seeking better lives. Human understanding of ecosystems has never been greater, and yet even amid an abundance of data we are often confronted with our own ignorance about the world around us. Most important, human intervention in ecosystems is evident everywhere, yet so little has been done to protect them that we must not delay our actions.

The challenge for the 21st century, then, is to reconcile the demands of human development with the tolerances of nature. For this we have to understand the vulnerabilities and resilience of ecosystems. From the Foreword to this volume:

> *At the dawn of a new century, we have the ability to change the vital systems of this planet, for better or worse. To change them for the better, we must recognize that the well-being of people and ecosystems is interwoven and that the fabric is fraying. We need to repair it, and we have the tools at hand to do so. What better time than now?*