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Ecosystems and Human Well-being: Policy Responses, Volume 3

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Findings of the Responses Working Group
of the Millennium Ecosystem Assessment

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Ecosystems and Human Well-being: A Framework for Assessment
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Millennium Ecosystem Assessment: Objectives, Focus, and Approach

The Millennium Ecosystem Assessment was carried out between 2001 and 2005 to assess the consequences of ecosystem change for human well-being and to establish the scientific basis for actions needed to enhance the conservation and sustainable use of ecosystems and their contributions to human well-being. The MA responds to government requests for information received through four international conventions—the Convention on Biological Diversity, the United Nations Convention to Combat Desertification, the Ramsar Convention on Wetlands, and the Convention on Migratory Species—and is designed also to meet needs of other stakeholders, including the business community, the health sector, nongovernmental organizations, and indigenous peoples. The sub-global assessments also aimed to meet the needs of users in the regions where they were undertaken.

The assessment focuses on the linkages between ecosystems and human well-being and, in particular, on "ecosystem services." An ecosystem is a dynamic complex of plant, animal, and microorganism communities and the nonliving environment interacting as a functional unit. The MA deals with the full range of ecosystems—from those relatively undisturbed, such as natural forests, to landscapes with mixed patterns of human use and to ecosystems intensively managed and modified by humans, such as agricultural land and urban areas. Ecosystem services are the benefits people obtain from ecosystems. These include *provisioning services* such as food, water, timber, and fiber; *regulating services* that affect climate, floods, disease, wastes, and water quality; *cultural services* that provide recreational, aesthetic, and spiritual benefits; and *supporting services* such as soil formation, photosynthesis, and nutrient cycling. The human species, while buffered against environmental changes by culture and technology, is fundamentally dependent on the flow of ecosystem services.

The MA examines how changes in ecosystem services influence human well-being. Human well-being is assumed to have multiple constituents, including the *basic material for a good life*, such as secure and adequate livelihoods, enough food at all times, shelter, clothing, and access to goods; *health,* including feeling well and having a healthy physical environment, such as clean air and access to clean water; *good social relations,* including social cohesion, mutual respect, and the ability to help others and provide for children; *security,* including secure access to natural and other resources, personal safety, and security from natural and human-made disasters; and *freedom of choice and action,* including the opportunity to achieve what an individual values doing and being. Freedom of choice and action is influenced by other constituents of well-being (as well as by other factors, notably education) and is also a precondition for achieving other components of well-being, particularly with respect to equity and fairness.

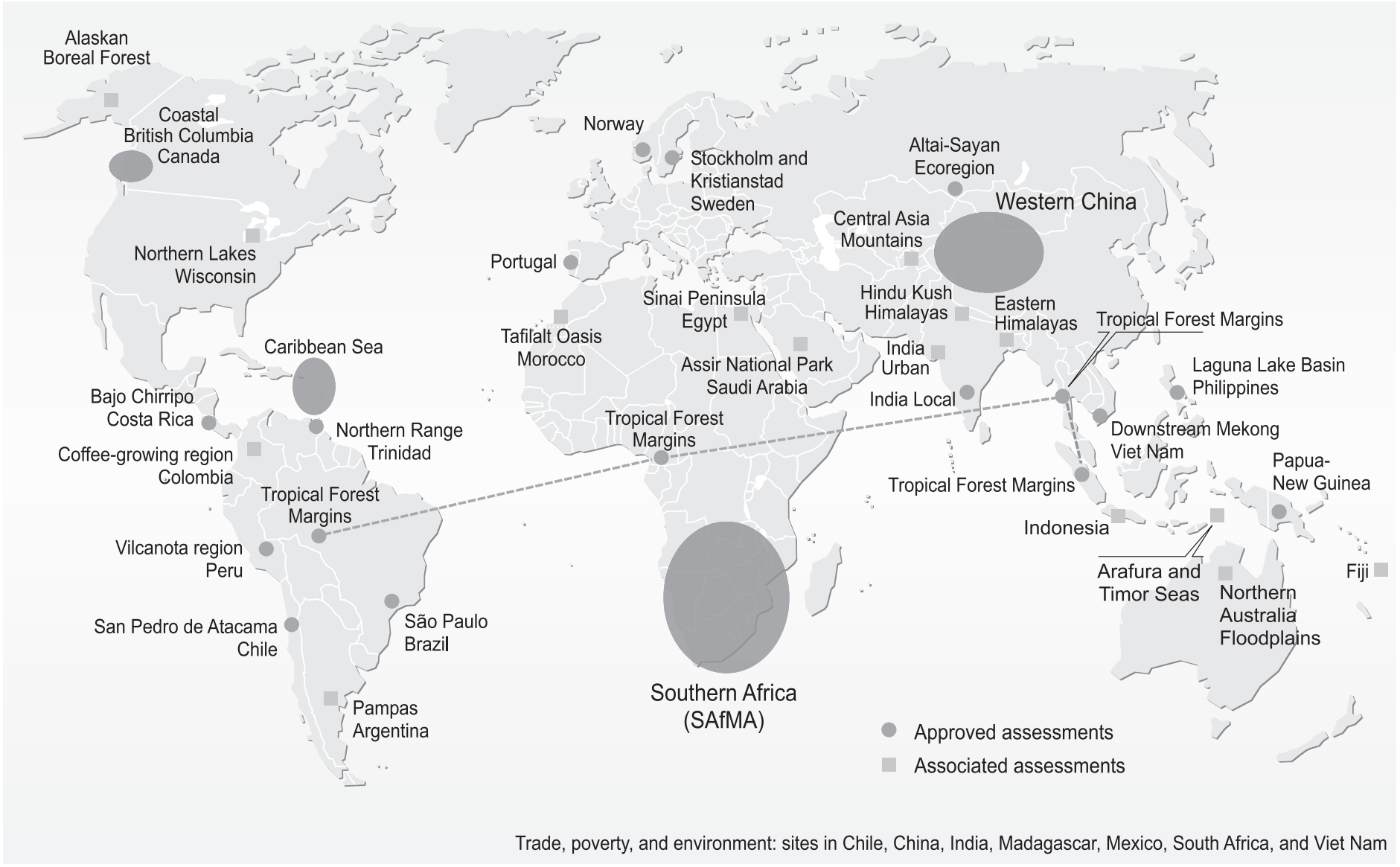
The conceptual framework for the MA posits that people are integral parts of ecosystems and that a dynamic interaction exists between them and other parts of ecosystems, with the changing human condition driving, both directly and indirectly, changes in ecosystems and thereby causing changes in human well-being. At the same time, social, economic, and cultural factors unrelated to ecosystems alter the human condition, and many natural forces influence ecosystems. Although the MA emphasizes the linkages between ecosystems and human well-being, it recognizes that the actions people take that influence ecosystems result not just from concern about human well-being but also from considerations of the intrinsic value of species and ecosystems. Intrinsic value is the value of something in and for itself, irrespective of its utility for someone else.

The Millennium Ecosystem Assessment synthesizes information from the scientific literature and relevant peer-reviewed datasets and models. It incorporates knowledge held by the private sector, practitioners, local communities, and indigenous peoples. The MA did not aim to generate new primary knowledge but instead sought to add value to existing information by collating, evaluating, summarizing, interpreting, and communicating it in a useful form. Assessments like this one apply the judgment of experts to existing knowledge to provide scientifically credible answers to policy-relevant questions. The focus on policy-relevant questions and the explicit use of expert judgment distinguish this type of assessment from a scientific review.

Five overarching questions, along with more detailed lists of user needs developed through discussions with stakeholders or provided by governments through international conventions, guided the issues that were assessed:

- What are the current condition and trends of ecosystems, ecosystem services, and human well-being?
- What are plausible future changes in ecosystems and their ecosystem services and the consequent changes in human well-being?
- What can be done to enhance well-being and conserve ecosystems? What are the strengths and weaknesses of response options that can be considered to realize or avoid specific futures?
- What are the key uncertainties that hinder effective decision-making concerning ecosystems?
- What tools and methodologies developed and used in the MA can strengthen capacity to assess ecosystems, the services they provide, their impacts on human well-being, and the strengths and weaknesses of response options?

The MA was conducted as a multiscale assessment, with interlinked assessments undertaken at local, watershed, national, regional, and global scales. A global ecosystem assessment cannot easily meet all the needs of decision-makers at national and sub-national scales because the management of any



Eighteen assessments were approved as components of the MA. Any institution or country was able to undertake an assessment as part of the MA if it agreed to use the MA conceptual framework, to centrally involve the intended users as stakeholders and partners, and to meet a set of procedural requirements related to peer review, metadata, transparency, and intellectual property rights. The MA assessments were largely self-funded, although planning grants and some core grants were provided to support some assessments. The MA also drew on information from 16 other sub-global assessments affiliated with the MA that met a subset of these criteria or were at earlier stages in development.

SUB-GLOBAL ASSESSMENT	ECOSYSTEM TYPES										ECOSYSTEM SERVICES								
	COASTAL	CULTIVATED	DRYLAND	FOREST	INLAND WATER	ISLAND	MARINE	MOUNTAIN	POLAR	URBAN	FOOD	WATER	FUEL and ENERGY	BIODIVERSITY-RELATED	CARBON SEQUESTRATION	FIBER and TIMBER	RUNOFF REGULATION	CULTURAL, SPIRITUAL, AMENITY	OTHERS
Altai-Sayan Ecoregion			●	●	●			●			●		●	●		●		●	
San Pedro de Atacama, Chile			●		●						●	●		●			●	●	●
Caribbean Sea	●					●	●				●	●		●				●	
Coastal British Columbia, Canada	●			●	●			●			●			●		●	●	●	
Bajo Chirripo, Costa Rica		●		●	●						●	●		●		●		●	●
Tropical Forest Margins		●		●							●	●		●	●	●	●		●
India Local Villages		●		●	●						●	●	●	●		●	●	●	●
Glomma Basin, Norway		●		●	●			●			●		●			●		●	●
Papua New Guinea	●	●				●	●				●	●	●	●		●	●	●	●
Vilcanota, Peru		●	●					●			●	●		●			●	●	●
Laguna Lake Basin, Philippines		●		●	●						●	●		●	●			●	●
Portugal	●	●	●	●	●	●	●	●		●	●	●		●	●	●	●	●	●
São Paulo Green Belt, Brazil	●	●		●	●					●	●	●		●	●	●	●	●	●
Southern Africa	●	●	●	●	●					●	●	●	●	●		●		●	●
Stockholm and Kristianstad, Sweden		●			●					●	●	●		●	●	●	●	●	●
Northern Range, Trinidad	●			●	●			●			●	●		●		●	●	●	●
Downstream Mekong Wetlands, Viet Nam	●	●			●						●	●	●	●	●	●	●	●	●
Western China		●	●	●	●			●			●	●		●	●		●		●
Alaskan Boreal Forest				●	●						●					●		●	●
Arafura and Timor Seas	●					●	●				●			●	●				●
Argentine Pampas		●									●	●						●	●
Central Asia Mountains								●			●	●		●					●
Colombia coffee-growing regions		●						●			●	●		●				●	
Eastern Himalayas				●				●			●	●	●	●				●	
Sinai Peninsula, Egypt			●					●						●			●	●	●
Fiji	●					●					●	●	●						●
Hindu Kush-Himalayas					●			●				●		●			●	●	●
Indonesia	●					●	●				●			●					●
India Urban Resource										●	●	●	●	●	●			●	●
Tafilalt Oasis, Morocco		●	●								●	●						●	●
Northern Australia Floodplains					●						●	●		●			●	●	●
Assir National Park, Saudi Arabia		●		●				●			●						●	●	●
Northern Highlands Lake District, Wisconsin				●	●							●				●	●	●	●

particular ecosystem must be tailored to the particular characteristics of that ecosystem and to the demands placed on it. However, an assessment focused only on a particular ecosystem or particular nation is insufficient because some processes are global and because local goods, services, matter, and energy are often transferred across regions. Each of the component assessments was guided by the MA conceptual framework and benefited from the presence of assessments undertaken at larger and smaller scales. The sub-global assessments were not intended to serve as representative samples of all ecosystems; rather, they were to meet the needs of decision-makers at the scales at which they were undertaken. The sub-global assessments involved in the MA process are shown in the Figure and the ecosystems and ecosystem services examined in these assessments are shown in the Table.

The work of the MA was conducted through four working groups, each of which prepared a report of its findings. At the global scale, the Condition and Trends Working Group assessed the state of knowledge on ecosystems, drivers of ecosystem change, ecosystem services, and associated human well-being around the year 2000. The assessment aimed to be comprehensive with regard to ecosystem services, but its coverage is not exhaustive. The Scenarios Working Group considered the possible evolution of ecosystem services during the twenty-first century by developing four global scenarios exploring plausible future changes in drivers, ecosystems, ecosystem services, and human well-being. The Responses Working Group examined the strengths and weaknesses of various response options that have been used to manage ecosystem services and identified promising opportunities for improving human well-being while conserving ecosystems. The report of the Sub-global Assessments Working Group contains lessons learned from the MA sub-global assessments. The first product of the MA—*Ecosystems and Human Well-being: A Framework for Assessment,* published in 2003—outlined the focus, conceptual basis, and methods used in the MA. The executive summary of this publication appears as Chapter 1 of this volume.

Approximately 1,360 experts from 95 countries were involved as authors of the assessment reports, as participants in the sub-global assessments, or as members of the Board of Review Editors. The latter group, which involved 80 experts, oversaw the scientific review of the MA reports by governments and experts and ensured that all review comments were appropriately addressed by the authors. All MA findings underwent two rounds of expert and governmental review. Review comments were received from approximately 850 individuals (of which roughly 250 were submitted by authors of other chapters in the MA), although in a number of cases (particularly in the case of governments and MA-affiliated scientific organizations), people submitted collated comments that had been prepared by a number of reviewers in their governments or institutions.

The MA was guided by a Board that included representatives of five international conventions, five U.N. agencies, international scientific organizations, governments, and leaders from the private sector, nongovernmental organizations, and indigenous groups. A 15-member Assessment Panel of leading social and natural scientists oversaw the technical work of the assessment, supported by a secretariat with offices in Europe, North America, South America, Asia, and Africa and coordinated by the United Nations Environment Programme.

The MA is intended to be used:

- to identify priorities for action;
- as a benchmark for future assessments;
- as a framework and source of tools for assessment, planning, and management;
- to gain foresight concerning the consequences of decisions affecting ecosystems;
- to identify response options to achieve human development and sustainability goals;
- to help build individual and institutional capacity to undertake integrated ecosystem assessments and act on the findings; and
- to guide future research.

Because of the broad scope of the MA and the complexity of the interactions between social and natural systems, it proved to be difficult to provide definitive information for some of the issues addressed in the MA. Relatively few ecosystem services have been the focus of research and monitoring and, as a consequence, research findings and data are often inadequate for a detailed global assessment. Moreover, the data and information that are available are generally related to either the characteristics of the ecological system or the characteristics of the social system, not to the all-important interactions between these systems. Finally, the scientific and assessment tools and models available to undertake a cross-scale integrated assessment and to project future changes in ecosystem services are only now being developed. Despite these challenges, the MA was able to provide considerable information relevant to most of the focal questions. And by identifying gaps in data and information that prevent policy-relevant questions from being answered, the assessment can help to guide research and monitoring that may allow those questions to be answered in future assessments.

Contents

Foreword

The Millennium Ecosystem Assessment was called for by United Nations Secretary-General Kofi Annan in 2000 in his report to the UN General Assembly, *We the Peoples: The Role of the United Nations in the 21st Century.* Governments subsequently supported the establishment of the assessment through decisions taken by three international conventions, and the MA was initiated in 2001. The MA was conducted under the auspices of the United Nations, with the secretariat coordinated by the United Nations Environment Programme, and it was governed by a multistakeholder board that included representatives of international institutions, governments, business, NGOs, and indigenous peoples. The objective of the MA was to assess the consequences of ecosystem change for human well-being and to establish the scientific basis for actions needed to enhance the conservation and sustainable use of ecosystems and their contributions to human well-being.

This volume has been produced by the MA Responses Working Group and examines the strengths and weaknesses of various response options that have been used to manage ecosystem services, as well as identifying promising opportunities for improving human well-being while conserving ecosystems. The material in this report has undergone two extensive rounds of peer review by experts and governments, overseen by an independent Board of Review Editors.

This is one of four volumes (*Current State and Trends, Scenarios, Policy Responses,* and *Multiscale Assessments*) that present the technical findings of the Assessment. Six synthesis reports have also been published: one for a general audience and others focused on issues of biodiversity, wetlands and water, desertification, health, and business and ecosystems. These synthesis reports were prepared for decision-makers in these different sectors, and they synthesize and integrate findings from across all of the working groups for ease of use by those audiences.

This report and the other three technical volumes provide a unique foundation of knowledge concerning human dependence on ecosystems as we enter the twenty-first century. Never before has such a holistic assessment been conducted that addresses multiple environmental changes, multiple drivers, and multiple linkages to human well-being. Collectively, these reports reveal both the extraordinary success that humanity has achieved in shaping ecosystems to meet the need of growing populations and economies and the growing costs associated with many of these changes. They show us that these costs could grow substantially in the future, but also that there are actions within reach that could dramatically enhance both human well-being and the conservation of ecosystems.

A more exhaustive set of acknowledgements appears later in this volume but we want to express our gratitude to the members of the MA Board, Board Alternates, Exploratory Steering Committee, Assessment Panel, Coordinating Lead Authors, Lead Authors, Contributing Authors, Board of Review Editors, and Expert Reviewers for their extraordinary contributions to this process. (The list of reviewers is available at www.MAweb.org.) We also would like to thank the MA Secretariat and in particular the staff of the Responses Working Group Technical Support Unit for their dedication in coordinating the production of this volume, as well as the Institute of Economic Growth (India) and the National Institute of Public Health and the Environment (Netherlands), which housed this TSU.

We would particularly like to thank the Co-chairs of the Responses Working Group, Kanchan Chopra and Rik Leemans, and the TSU Coordinators, Pushpam Kumar and Henk Simons, for their skillful leadership of this working group and their contributions to the overall assessment.

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Preface

The focus of the MA is on ecosystem services (the benefits people obtain from ecosystems), how changes in ecosystem services have affected human well-being in the past, and what role these changes could play in the present as well as in the future. The MA is an assessment of responses that are available to improve ecosystem management and can thereby contribute to the various constituents of human well-being. The specific issues addressed have been defined through consultation with the MA users. Broadly, the MA applies an integrated systems' approach to evaluate trade-offs involved in following alternate strategies and courses of action to use ecosystem services for enhancing human welfare.

The overall aims of the MA are to:

- identify priorities for action;
- provide tools for planning and management;
- provide foresight concerning the consequences of decisions affecting ecosystems;
- identify response options to achieve human development and sustainability goals; and
- help build individual and institutional capacity to undertake integrated ecosystem assessments and to act on their findings.

The MA synthesizes information from scientific literature, data sets, and scientific models, and utilizes knowledge held by the private sector, practitioners, local communities, and indigenous peoples. All of the MA findings have undergone two rounds of expert and governmental review.

This report of the MA Responses Working Group evaluates the current understanding of how human decisions and policies influence ecosystems, ecosystem services, and consequently, human well being. The assessment identifies and critically evaluates past, current, and possible future policy and management options for maintaining ecosystems (including biodiversity) and sustaining the flow of ecosystem services. The Responses Working Group is one of four MA working groups, each of which has contributed an assessment report. The Condition and Trends Working Group reviewed the state of knowledge on ecosystems, ecosystem services, and associated human well-being in the present, recent past, and near future. The Scenarios Working Group considered the evolution of ecosystem services during the first half of the twenty-first century under a range of plausible narratives. The Sub-global Working Group carried out assessments at different levels to directly meet needs of local and regional decision-makers and strengthen the global findings with finer-scale detail. Together, the working group reports provide local, national, regional, and global perspectives and information.

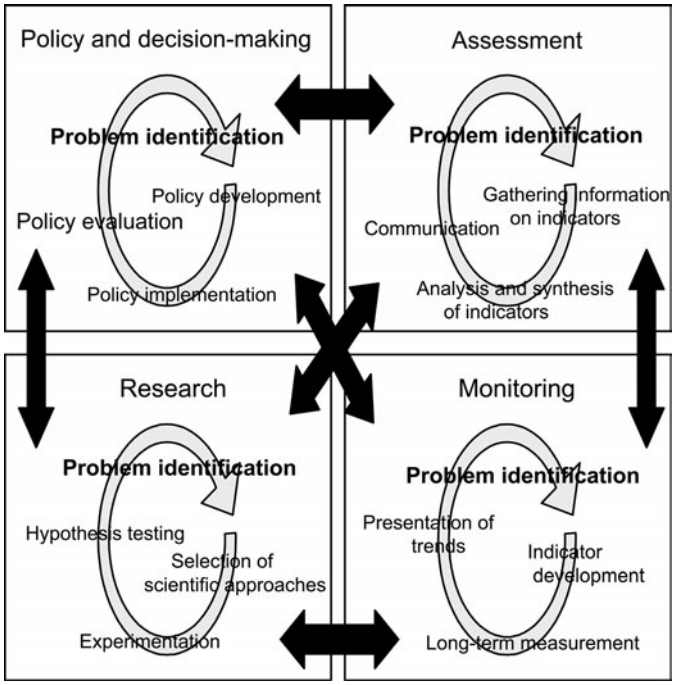
In the MA, responses are defined as the whole range of human actions, including policies, strategies, and interventions, to address specific issues, needs, opportunities, or problems. A response typically involves a ''reaction to a perceived problem.'' It can be individual or collective; it may be designed to answer one or many needs; or it could be focused at different temporal, spatial, or organizational scales. In the context of managing ecosystems or ecosystem services, responses may be of legal, technical, institutional, economic, or behavioral nature and may operate at local/micro, regional, national, or international level at the time scale of days to hundred of years. The assessment focuses on responses that are intended to ensure that ecosystems and biodiversity are preserved, that desired ecosystem services accrue, and that human well-being is augmented. This is one of the major objectives of all conventions targeted by the MA, the Millennium Development Goals, and others.

Focus of the Responses Assessment Report

The Responses assessment report is rooted in the MA conceptual framework, which provides an understanding of the causes and consequences of changes in ecosystems across scales (local, regional, and global) and over time (MA 2003; see also Chapter 1 of this volume). *Ecosystems, ecosystem services, human well-being, and direct and indirect drivers initiating the links among them constitute the main elements of the MA conceptual framework.* (See Chapter 1 for definitions of these concepts.) Human responses are outcomes of human decisions and they influence and change the key connecting links between these elements. They determine how individuals, communities, nations, and international agencies intervene or strategize, ostensibly in their own interests, to use, manage, and conserve ecosystems. There are many ways to categorize responses, which are often determined by the problem at hand, the decision-maker/actor associated with, or the tradition of, the discipline.

The organizational scales of responses can be international (for instance, the U.N. conventions), multilateral and bilateral (important for transboundary problems), national, state/provincial, community (urban or rural), family, or individual. Decisions taken at each of these levels can affect ecosystems and ecosystem services. For example, national policies initiated to comply with international trade treaties can impact local ecosystems. The assessment methodology developed by the Responses Working Group is comprehensive enough to be used to assess responses at all scales, as and when they are relevant to the context of the particular ecosystem service being studied. The Responses assessment consists of a three-stage approach. The first stage focuses on factors that may either rule out a particular response or may define the critical preconditions for its success. Constraints that render a policy option infeasible are called the *binding constraints,* which are context specific. In the second stage, responses are compared across multiple dimensions, identifying compatibility or conflict between different policy objectives. Here the acceptable costs associated with the implementation of a response (the *acceptable trade-offs*) are identified. Finally, responses are evaluated from different perspectives in order to provide guidance that is the best balanced from the point of view of decision-making as shown in the illustration below:

As shown in the illustration, research, assessment, monitoring, and policy-making are all components of a continuing interactive



process to support development and implementation of responses. Decision-making starts by identifying a problem, followed by collating the research findings to help in defining and choosing policy options. (See Chapter 18 of this volume.) Policies are selected, implemented, and then evaluated for their effectiveness. The process is iterative and involves interaction with all kinds of information providers. Ideally, the decision-making cycle entails obtaining feedback from all categories of stakeholders. Similar loops exist for the research, monitoring, and assessment process, each with its characteristic objectives, approaches, and dynamics. Under the best circumstances, research insights should yield adequate monitoring networks and indicators of change, to be taken up for assessment toward an informed decision process. Understandably, the dynamics and timing of each of these cycles do not always evolve in perfect coordination with each other. The dynamic nature of information exchange and feedback to and from these processes and their stakeholders are integral to developing responses.

This implies that decision-making processes are liable to change over time to improve effectiveness. A number of mechanisms can facilitate this. Ecosystem dynamics will never be completely understood, socioeconomic systems will continue to change, and drivers can never be fully anticipated. It is important therefore that decision-making processes incorporate, wherever possible, procedures to evaluate outcomes of actions and assimilate lessons learned from experience. Debate on exactly how to go about doing this continues in discussions on adaptive management, social learning, safe minimum standards, and the precautionary principle. But the core message of all approaches is the same: acknowledge the limits of human understanding, give special consideration to irreversible changes, and evaluate the multiple impacts of decisions as they unfold.

Organization of this Volume

This assessment report has a large canvas to cover. Various response options are selected on the basis of the impact they have on a set of ecosystems and ecosystem services. The report examines these different societal responses and evaluates them by using diverse methodologies. The results are analyzed from diverse perspectives to draw key conclusions regarding their impact on human well-being.

To facilitate the analysis, this report is divided into three parts. Part I (that is, Chapters 1 through 4) introduces responses and focuses mainly on conceptual and methodological issues. Chapter 1 summarizes the MA conceptual framework and defines some important concepts. Chapter 2 discusses alternative typologies of possible responses. It differentiates responses by, actors, disciplines, drivers, and scales, and further characterizes them in terms of the instruments for intervention—such as economic, institutional, governance, and technological—thus highlighting the multidimensional nature of responses.

Chapter 3 elaborates on alternate methods of assessing responses. It sets up a framework that can be used to evaluate whether particular responses are effective and desirable from social, political, and economic perspectives. It indicates how social, political, and economic factors and their actors can act as constraints to the ability of responses or strategies to meet intended goals and avoid unintended consequences.

Chapter 4 highlights specific decision-making criteria in the above context. It also focuses on the role of uncertainty in assessing the effectiveness of responses. This uncertainty is partly a function of the methodology and tools applied but also an inherent characteristic of decision-making that is always a leap into the future.

Part II consists of ten chapters (5 through 14), each focusing on one or more ecosystem service. These chapters relate specific case studies from the literature and the sub-global assessments to the response typology and evaluation methodology outlined in Part I. Chapter 5 focuses on responses concerning biodiversity, which underlies all other ecosystem services. This chapter has a strong spotlight on ecosystem management and conservation.

Chapters 6, 7, and 8 dwell on the provisioning ecosystem services. Different responses at all major decision-making levels, which alter ecosystems providing these services, are presented and assessed. Special emphasis is laid upon the trade-offs and synergies between specific responses and their consequences. Responses that contribute to the sustainable use of these ecosystems are highlighted. In a similar vein, Chapters 9 through 13 focus on regulating services, and Chapter 14 assesses cultural ecosystem services. These chapters correspond to chapters pertaining to ecosystem services presented by the Condition and Trends Working Group. Together, the ecosystem services chapters in this volume and in MA *Current State and Trends* provide a complete overview of the current understanding of where, how, and why ecosystem services are changing; in what way the selected responses are having an impact on drivers, ecosystems, ecosystem services; and the different constituent parts of human well-being.

Taking an ecosystem service approach proved difficult for some of the chapters in Part II. For instance, few responses focus directly on managing ecosystems services toward climate regulation or waste management. Additionally, there has been no or little experience in treating the topics in some chapters (for example, waste management and climate regulations) as ecosystem services. Adhering too strongly to an ecosystem services approach could, in some cases, lead to too narrow a focus while the user audiences expect a broader treatment. This became apparent after the first review. We have therefore permitted a more user-oriented treatment of certain ecosystem services to allow for more comprehensive discussions of responses related to areas such as climate regulation, waste management, and disease control.

Chapter 15 deals with responses that address (provision of) ecosystem services across a number of systems simultaneously, explicitly including objectives to enhance human well being. Such integrated responses occurring across different scales could be oriented at different actors, generally employing a range of instruments for implementation. The assessment of sustainable management strategies and trade-offs between different responses is central here. The responses always integrate different aspects of ecosystems. Examples include integrated water, forest, or coastal management. Such responses may be at the international level in the form of framework conventions or at local levels in the form of concrete resource management projects. This chapter provides a comprehensive evaluation of such integrated responses.

Part III (Chapters 15 through 19) synthesizes the lessons learned from earlier chapters and provides an overarching evaluation of the interlinkages among drivers, ecosystems, ecosystem services, and ultimately, human well-being. Chapter 15 deals with responses that address (provision of) ecosystem services across a number of systems simultaneously, explicitly including objectives to enhance human well-being. Such integrated responses occurring across different scales could be oriented at different actors, generally employing a range of instruments for implementation. The assessment of sustainable management strategies and trade-offs between different responses is central here. The responses always integrate different aspects of ecosystems. Examples include integrated water, forest, or coastal management. Such responses may be at the international level in the form of framework conventions or at local levels in the form of concrete resource management projects. This chapter provides a comprehensive evaluation of such integrated responses.

The other chapters within Part III take on a specific aspect of human welfare for analysis such as material and social security, health, freedoms, and choice. Chapter 16 takes a strong human health perspective, while Chapter 17 emphasizes poverty reduction. The central questions in these chapters are:

- How have responses that were aimed at protecting ecosystems and their services, impacted the different constituents and determinants of human well-being?
- Did policies initiated at national levels for promoting well-being have negative impacts on ecosystems or on the accrual of ecosystem services?

These two chapters thus strongly emphasize the trade-offs and synergies between different responses.

Chapter 18 provides general ''guidelines'' for choosing responses, assessing the required information and decision-tools by discussing the relative strengths and weaknesses of alternate sources of information. Chapter 19 evaluates the Millennium Development Goals from a responses perspective. Sustainable use of ecosystems and thereby accrual of ecosystem services for human well-being is central to these chapters as in all others.

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Reader's Guide

The four technical reports present the findings of each of the MA Working Groups: Condition and Trends, Scenarios, Responses, and Sub-global Assessments. A separate volume, *Our Human Planet*, presents the summaries of all four reports in order to offer a concise account of the technical reports for decision-makers. In addition, six synthesis reports were prepared for ease of use by specific audiences: Synthesis (general audience), CBD (biodiversity), UNCCD (desertification), Ramsar Convention (wetlands), business and industry, and the health sector. Each MA sub-global assessment will also produce additional reports to meet the needs of its own audiences.

All printed materials of the assessment, along with core data and a list of reviewers, are available at www.MAweb.org. In this volume, Appendix A contains color maps and figures. Appendix B lists all the authors who contributed to this volume. Appendix C lists the acronyms and abbreviations used in this report and Appendix D is a glossary of terminology used in the technical reports. Throughout this report, dollar signs indicate U.S. dollars and ton means tonne (metric ton). Bracketed references within the Summary are to chapters within this volume.

In this report, the following words have been used where appropriate to indicate judgmental estimates of certainty, based on the collective judgment of the authors, using the observational evidence, modeling results, and theory that they have examined: very certain (98% or greater probability), high certainty (85–98% probability), medium certainty (65%–58% probability), low certainty (52–65% probability), and very uncertain (50–52% probability). In other instances, a qualitative scale to gauge the level of scientific understanding is used: well established, established but incomplete, competing explanations, and speculative. Each time these terms are used they appear in italics.

Ecosystems and Human Well-being: Policy Responses, Volume 3

Summary: Response Options and Strategies

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CONTENTS

Introduction

The Millennium Ecosystem Assessment examines the consequences of changes to ecosystem services for human well-being. It assesses the conditions and trends in ecosystems and their services, explores plausible scenarios for the future, and assesses alternative response options. The assessment of the Condition and Trends Working Group affirms that, in the aggregate, changes to ecosystems have contributed to substantial gains in human well-being over the past centuries: people are better nourished and live longer and healthier lives than ever before, incomes have risen, and political institutions have become more participatory. However, these gains have been achieved at growing costs, including the degradation of many ecosystem services, increased risks of nonlinear changes, and the exacerbation of poverty for some groups of people. Persistent and significant local, national, and regional disparities in income, well-being, and access to ecosystem services continue to exist. The assessment of the Scenarios Working Group shows that the degradation of ecosystem services could grow significantly worse during the first half of this century and represents a barrier to achieving the Millennium Development Goals.

The question arises: What kind of action can we take? What policies can be developed and implemented by societies to enable them to move in chosen directions? In this report, we define ''responses'' to encompass the entire range of human actions, including policies, strategies, and interventions, to address specific issues, needs, opportunities, or problems related to ecosystems, ecosystem services, and human well-being. Responses may be institutional, economic, social and behavioral, technological, or cognitive in nature. Response strategies are designed and undertaken at local, regional, or international scales within diverse institutional settings. This report assesses how successful various response strategies have been and identifies the conditions that have contributed to their success or failure. Additionally, it derives lessons that can be applied to the design of future responses.

The MA conceptual framework (MA 2003) posits that people are integral parts of ecosystems and that a dynamic interaction exists between them and other parts of ecosystems, with the changing human condition driving, both directly and indirectly, changes in ecosystems and thereby causing changes in human well-being. (See Chapter 1, Box 1.2.) Direct and indirect drivers operate at different spatial, temporal, and organizational scales. Responses affect the direct and indirect drivers of change in ecosystems and thereby the services derived from ecosystems. In this framework, human–ecosystem interactions are dynamic processes and, as a result, drivers and responses co-evolve over time. Expansion of cultivated systems, for instance, was initially a response to the growing demand for food. Over time, this expansion of cultivation became a driver of change altering other ecosystem services, particularly as a result of habitat conversion, use of water for irrigation, and the excessive use of nutrients. A full assessment of the effectiveness of various responses must thus include the examination of the historical and contemporary contexts within which interactions between drivers and responses developed. The choice of the most effective set of response options needs to be informed not just by the impact of the response on a particular driver, but also by the interactions among different drivers themselves.

The effectiveness and impact of any response strategy depends furthermore on the interactions between the people who initiate the response and others who have a stake in the outcomes at local, regional, and global levels. Strategies initiated at the global level, such as through international conventions, for example, may have consequences on ecosystem services and human well-being at the local level.

The Responses Working Group assessed a wide range of responses and interventions undertaken by different decision-makers in many different economic, social, and institutional settings. In the sections that follow, this summary describes several key characteristics of successful responses, discusses methods for choosing responses, and reviews some of the more promising or effective responses. It also discusses some of the barriers to implementing promising responses; one barrier that deserves particular emphasis involves the limited number of trained people in many countries who are able to analyze response options and to develop and implement programs of action to address these problems. This assessment demonstrates the tremendous scope for actions that can help to enhance human well-being while conserving ecosystems; but without investment in the necessary human and institutional capacity, many countries will not be able to effectively pursue these options.

Characteristics of Successful Responses

Responses to environmental problems tend to be more successful when: a) there is effective coordination among the different levels of decision-making; b) transparent participatory approaches are used; c) the potential trade-offs and synergies among response strategies and their outcomes are factored into their design; and d) considerations of impacts on ecosystems and the potential contributions of ecosystem services are mainstreamed in economic policy and development planning.

Coordination across Sectors and across Scales

Effective action to address problems related to ecosystem services requires improved coordination across sectors and scales. **[See especially 5, 17, 19]**

Almost any action affecting an ecosystem has consequences for many different services provided by that ecosystem. For example, a response designed to enhance the production of one ecosystem service, such as crop production, could harm other services such as water quality, fisheries production, or flood control. These trade-offs cannot be adequately addressed through traditional sectoral management approaches. Moreover, they cannot be adequately addressed through actions undertaken at a single scale, whether international, national, or local. Effective ecosystem management thus requires effective coordination, both among governmental institutions directly responsible for the environment and between those institutions and other sectors. [17]

Coordination among International Institutions

The cooperation among multilateral environmental agreements has improved in recent years, but considerable scope remains to increase the coordination and consistency among their objectives and actions. [17] To date, however, there has been relatively little effective coordination between MEAs and the politically stronger international economic and social institutions such as the World Bank (except in its role as an implementing agency of the Global Environment Facility), the International Monetary Fund, and the World Trade Organization. Despite their profound influence on the environment, economic and trade-related agreements have shown minimal commitment to environmental issues; neither have the poverty reduction strategies prepared by countries for the World Bank. Given the central importance of ecosystem services in achieving many Millennium Development Goals (in par-

ticular, the goals and targets related to poverty, hunger, disease, children's health, water, and environmental sustainability), the MDG process could in principle provide a means to better incorporate the environment into these other sectors, but little progress has yet been observed. [19]

Coordination across Decision-making Levels

International agreements are more likely to be translated into national policy if they include precise obligations, sanctions for violation, and monitoring provisions, and if they provide financial assistance for national implementation. While most MEAs meet some of these criteria, relatively few have sanctions for violation; in almost all cases, there is considerable scope for the agreements to be strengthened if the criteria were met more effectively. [17] For example, financial mechanisms such as the Global Environment Facility enable assistance to be provided through some ecosystem-related MEAs, but across the board these agreements would be more effective if greater assistance were available. Similarly, the Convention on Biological Diversity, the Convention to Combat Desertification, and the Ramsar Wetlands Convention could be strengthened if countries assumed additional outcome-focused obligations in addition to the more common planning and reporting obligations. The CBD, for example, has now established a specific outcome-focused target—the ''2010 Target'' to significantly slow the rate of biodiversity loss—but this target is not binding on individual countries.

Some steps have been taken by the ecosystem-focused MEAs to promote greater national implementation. For example, the national biodiversity strategies and action plans form a central implementation mechanism of the CBD and have resulted in some action at the national and local levels.[5] The CCD has encouraged the development of national action programs to combat desertification; 50 of these programs are now receiving international funding. While the CBD national biodiversity strategies and the CCD national action programs have stimulated and guided some actions and policy reforms, their primary impact has been within the environmental sector; they have been less effective in influencing action in other sectors. The overall effectiveness of the implementation of these and other MEAs could be strengthened if these planning processes were more effectively integrated into other processes such as decentralization and land reform, which generally have major effects on land use and desertification.

In general, international agreements dealing with ecological resources tend to be less successful than those concerning defense or trade because of the less obvious nature of reciprocal benefits to contracting parties, the major driving force in other agreements. Success of international legal instruments depends on the perception of the need for longer term cooperation. The design of the agreement and the manner in which the agreement was negotiated both play a role. Given the complexity of some negotiating processes and the lack of resources to enable the full participation of many developing countries in negotiations, some countries face serious challenges in ensuring adequate representation of their interests and perspectives in international agreements; this in turn undermines the effectiveness of the agreements. [17] Clearly, there exists an urgent need to augment developing-country capacity to participate in international negotiations.

Coordination at National and Sub-national Levels

At national and sub-national levels, effective responses to ecosystem degradation are constrained by the same weakness of cross-sectoral coordination and even coordination within the environmental sector. The implementation of many environmental conventions at a national level, for example, could be strengthened through more effective coordination among the national offices responsible for implementing different international agreements. More generally, at the national and sub-national levels successful response interventions often involve situation-driven integration across decision-making agencies. This type of integration tends to be found in situations where communities and lower level governments are given management and decision-making flexibility within broad enabling frameworks.

Participation and Transparency

Insufficient participation and transparency in planning and decision-making have been major barriers to the design and implementation of effective responses. **[3, 4, 5, 7, 14, 15, 17]**

The importance of stakeholder participation is now widely recognized, although generally poorly implemented, at the international scale, as well as at the national and local scales. Although stakeholder participation can result in a slower and more costly process, it creates ownership in the policy being developed, commitment to successful implementation, and increased societal acceptance of the policy. Among international conventions, for example, the CBD states ''management should be decentralized to the lowest appropriate level, and boundaries for management shall be defined by indigenous and local peoples, among others.'' The 1999 Ramsar Convention Conference of Parties adopted guidelines for the inclusion of local and indigenous people in the management of Ramsar wetlands. The problems associated with inadequate stakeholder participation are most apparent in the area of biodiversity conservation. Because local people are de facto the primary resource managers in most regions, working with local communities is essential to conserving biodiversity in the longer term. The establishment of protected areas, for example, is more effective when local communities have ''bought in'' to the protected area and have alternative livelihood opportunities or receive direct payments so that they are not harmed by creation of the proteced area. [5] This often requires the establishment of protected areas designed to support multiple uses of natural and cultural resources. Bottom-up decision-making processes rooted in a local and site-specific context have also enabled the negotiation of water agreements to become a catalyst for peace and cooperation. Note, for instance, that nation states belonging to very different political persuasions confirm water treaties such as the Nile treaty and the Indus Waters treaty. [7]

Important as stakeholder participation is, the financial costs and time needed for elaborate stakeholder processes can sometimes outweigh the benefits. Moreover, there is also the risk that ''participation'' can be co-opted into what are, at their core, centrally determined plans. This kind of ''centralized decentralization'' may well lead to the exclusion of disadvantaged groups even though they have been ''consulted'' in the decision process. Often this is the consequence of policies that do not take into account differences among stakeholders in preexisting situations. Examples are found in the watershed programs and the water user associations in India.

The introduction of participatory approaches in settings where people are not accustomed to such approaches must be accompanied by capacity-building among stakeholders if it is to succeed. The capacity created in this way must also be sustained. Key interventions include both public education and steps taken to strengthen social networks in order to facilitate the inclusion of all relevant forms of knowledge and information, including local and indigenous knowledge, in decision-making.

For participatory approaches to succeed, the stakeholders involved need access to information on both the resources being managed and the decision-making process. Effective monitoring, assessment, and reporting is therefore a key to success in allocating ecosystem services and implementing response options. Given the heterogeneity, constant change, and site-specific characteristics of ecosystem services and the human institutions through which they are managed, a fundamental but often overlooked need is for an independent and transparent process of assessment. Monitoring and assessment are critical components of pro-active adaptive management, as they can provide the feedback necessary to develop and continually improve implementation strategies as new information becomes available, constraints are identified, and enabling institutional structures put in place. Although considerable debate continues about the most effective mechanisms for stakeholder involvement in decision-making processes, all approaches agree on the same core elements: acknowledge the limits of human understanding, recognize knowledge gaps explicitly, give special consideration to irreversible changes, and evaluate the impacts of decisions as they unfold.

Trade-offs and Synergies

Trade-offs and synergies among human well-being, ecosystems, and ecosystem services are the rule rather than the exception and this implies that informed choices must be made to achieve the best possible outcomes. **[5, 6, 7, 8, 11, 13, 15, 16, 17]**

The following categories of trade-offs are involved in managing ecosystem services:

- *Trade-offs between the present and future.* For example, some technologies developed to increase food production, such as the replacement of traditional cultivars with high yielding varieties or the excessive application of fertilizers and pesticides, have reduced the capacity of land and water systems to provide food in the future. [6] Similarly, some resource management practices yield economic benefits in the present, but defer costs to the future. Forest harvest, for example, provides immediate economic returns but may result in future costs in the form of degraded water quality or increased frequency of floods.
- *Trade-offs among ecosystem services.* The majority of response strategies have given priority to increasing the allocation of provisioning services, such as food production and water supply, often at the expense of regulating and cultural ecosystem services. For example, water has been impounded to enable increased irrigation and increased food production, but this reduces downstream water supplies, harms freshwater biodiversity, and degrades some cultural and recreational benefits provided by free-flowing rivers.
- *Trade-offs among constituents of human well being.* Responses are often directed at improving the material well-being constituent of human well-being to the neglect of other constituents of human well-being such as health and security. For example, increased use of pesticides can increase the production of food, but harm the health of farmworkers and consumers.
- *Trade-offs among stakeholders.* Ecosystems and their services are used differently by different groups of stakeholders: the needs of vulnerable groups are often marginalized in this process. For example, large scale commercial exploitation of forests for timber harvest often comes at the expense of the use of forests by local communities as a source of non-wood forest products. [8] Similarly, the conversion of mangrove forests to shrimp aquaculture benefits the farmers who have resources to invest in aquaculture operations, but harms the local fisherfolk who depend on capture fisheries associated with the mangroves.

Although negative trade-offs are common, positive synergies are also possible, and responses can be identified that create synergies and help in achieving multiple objectives. The long-term success of conservation strategies in areas where local people are dependent on the use of biological resources, for example, depends on meeting the needs of these communities. The exact nature of the synergy is more easily identified in specific ecological and societal contexts through an appropriate understanding of linkages between ecosystems and human well-being. Similarly, among the growing number of people who face health problems associated with obesity, reducing consumption of food would benefit both human health and reduce demand for ecosystem services.

Some potential and emerging synergies can only be realised if enabling institutions are created. For example, afforestation, reforestation, improved forest, cropland and rangeland management and agroforestry provide a range of opportunities to increase carbon sequestration. Similarly, slowing deforestation provides an opportunity to reduce carbon emissions. Such activities have the potential to sequester about 10 to 20% of projected fossil emissions up to 2050. [13] However, only a small part of this potential can be delivered with the institutions, technologies, and financial arrangements now in place. A large number of these issues remain undecided and prevent the use of forestry as a carbon management option.

Mainstreaming

The quantity and quality of ecosystem services available are often determined to a greater extent by macroeconomic, trade, and other policies than by policies within the environmental sector itself. **[5, 6, 8, 17, 19]**

Some of the most significant drivers of change in ecosystem services and their use originate outside the sectors that have responsibility for the management of ecosystem services. For example, the availability of fish in coastal waters can be strongly influenced by government policies related to crop production or food price supports, since this will influence the amount of fertilizer and water used in crop production and hence the potential harmful impacts associated with nutrient pollution or changes in river flows. Similarly, trade policies can have significant impacts on forest product industries and thus on the management of forests. Indeed, this assessment finds that policies outside the forest sector are often more important than policies within the sector in determining the social and ecological sustainability of forest management. While inappropriate policies in other sectors can harm ecosystem services, changes in those policies can often also provide one of the most effective means for improving managment of ecosystem services. For example, reforms to the Common Agricultural Policy in Europe to incorporate environmental dimensions could significantly reduce pressures on some ecosystem services. [6]

In general, potential threats to ecosystem services and the potential contributions of ecosystem services to economic development and poverty reduction are not taken into account in development plans and trade policies. Very few macroeconomic responses to poverty reduction have considered the importance of sound management of ecosystem services as a mechanism to meet the basic needs of the poorest. The poverty reduction strategies that many developing countries are now preparing for the World Bank and other donors can be most effective if they include an emphasis on the links between ecosystems and human

well-being, but few of the strategies incorporate these issues. [17] More generally, the failure to incorporate considerations of ecosystem management in the strategies being pursued to achieve many of the eight Millennium Development Goals will undermine the sustainability of any progress that is made toward the goals and targets associated with poverty, hunger, disease, child mortality, and access to water, in particular. [19]

Choosing Responses

Decisions affecting ecosystems and their services can be improved by changing the processes used to reach those decisions. [18]

The context of decision-making about ecosystems is changing rapidly. The new challenge to decision-making is to make effective use of information and tools in this changing context in order to improve the decisions. At the same time, some old challenges must still be addressed. The decision-making process and the actors involved influence the intervention chosen. Decision-making processes vary across jurisdictions, institutions, and cultures. Even so, this assessment has identified the following elements of decision-making processes related to ecosystems and their services that tend to improve the decisions reached and their outcomes for ecosystems and human well-being:

- use the best available information, including considerations of the value of both marketed and nonmarketed ecosystem services;
- ensure transparency and the effective and informed participation of important stakeholders;
- recognize that not all values at stake can be quantified, and thus quantification can provide a false objectivity in decision-making processes that have significant subjective elements;
- strive for efficiency, but not at the expense of effectiveness;
- consider equity and vulnerability in terms of the distribution of costs and benefits;
- ensure accountability and provide for regular monitoring and evaluation; and
- consider cumulative and cross-scale effects and, in particular, assess trade-offs across different ecosystem services.

A wide range of tools can assist decision-making concerning ecosystems and their services. [3, 4] The use of decision-making methods that adopt a pluralistic perspective is particularly pertinent, since these techniques do not give undue weight to any particular viewpoint. Examples of tools that can assist decision-making at a variety of scales, including global, subglobal, and local, include:

- *Deliberative tools (which facilitate transparency and stakeholder participation).* These include neighborhood forums, citizens' juries, community issues groups, consensus conferences, electronic democracy, focus groups, issue forums, and ecosystem service user forums.
- *Information-gathering tools (which are primarily focused on collecting data and opinions).* Examples of information-gathering tools include citizens' research panels, deliberative opinion polls, environmental impact assessments, participatory rural appraisal, and rapid rural appraisal.
- *Planning tools (which are typically used to evaluate potential policy options).* Some common planning tools are consensus participation, cost-benefit analysis, multicriteria analysis, participatory learning and action, stakeholder decision analysis, trade-off analysis, and visioning exercises.

Some of these methods are particularly well-suited for decision-making in the face of uncertainties in data, prediction, context, and scale. [4] Such methods include cost-benefit or multicriteria analyses, risk assessment, the precautionary principle, and vulnerability analysis. (See Table R1.) All these methods have been able to support optimization exercises, but few of them have much to say about equity. Cost-benefit analysis can, for example, be modified to weight the interests of some people more than others. The discount rate can be viewed, in long-term analyses, as a means of weighting the welfare of future generations; and the precautionary principle can be expressed in terms of reducing the exposure of certain populations or systems whose preferential status may be the result of equity considerations. Multicriteria analysis was designed primarily to accommodate optimization across multiple objectives with complex interactions, but this can also be adapted to consider equity and threshold issues at national and sub-national scales.

Scenario-building exercises provide one way to cope with many aspects of uncertainty, but our limited understanding of ecological and human response processes shrouds any individual scenario in its own characteristic uncertainty. [4] The development of a set of scenarios provides a useful means to highlight the implications of alternative assumptions about critical uncertainties related to the behavior of human and ecological systems. In this way, they provide one means to cope with many aspects of uncertainty in assessing responses. The relevance, significance, and influence of scenarios ultimately depend on the assumptions made in their development. At the same time, though, there are a number of reasons to be cautious in the use of scenarios. First, individual scenarios represent conditional projections based on specific assumptions. Thus to the extent that our understanding and representation of the ecological and human systems represented in the scenarios is limited, specific scenarios are characterized by their own uncertainty. Second, there is uncertainty in translating the lessons derived from scenarios developed at one scale—say, global—to the assessment of responses at other scales—say, sub-national. Third, scenarios often have hidden and hard-to-articulate assumptions. Fourth, environmental scenarios have tended to more effectively incorporate state-of-the-art natural science modeling than social science modeling.

Effective management of ecosystems requires coordinated responses at multiple scales. [15, 17] Responses that are successful at a small scale are often less successful at higher levels due to constraints in legal frameworks and government institutions that prevent their success. In addition, there appear to be limits to scaling up, not only because of these higher-level constraints, but also because interventions at a local level often address only direct drivers of change rather than indirect or underlying ones. For example, a local project to improve livelihoods of communities surrounding a protected area in order to reduce pressure on it, if successful, may increase migration into buffer zones, thereby adding to pressures. Cross-scale responses may be more effective at addressing the higher-level constraints and leakage problems and simultaneously tackling regional and national as well as local-level drivers of change. Examples of successful cross-scale responses include some co-management approaches to natural resource management in fisheries and forestry and multistakeholder policy processes.

Active adaptive management can be a particularly valuable tool for reducing uncertainty about ecosystem management decisions. [17] The term "active" adaptive management is used here to emphasize the key characteristic of the original concept (which is frequently and inappropriately used to

Table R1. Applicability of Decision Support Methods and Frameworks

Key: ++ = direct application of the method by design
+ = possible application with modification or (in the case of uncertainty) the method has already been modified to handle uncertainty
– = weak but not impossible applicability with significant effort

Method	Optimization	Equity	Thresholds	Uncertainty	Scale of Application		
					Micro	National	Regional and Global
Cost-benefit Analysis	+	+	–		√	√	√
Risk Assessment	+	+	++	++	√	√	√
Multicriteria Analysis	++	+	+	+	√	√	
Precautionary Principle*	+	+	++	++	√	√	√
Vulnerability Analysis	+	+	++	+	√	√	

*The precautionary principle is not strictly analogous to the other analytical and assessment methods but still can be considered a method for decision support. The precautionary principle prescribes how to bring scientific uncertainty into the decision-making process by explicitly formalizing precaution and bringing it to the forefront of the deliberations. It posits that significant actions (ranging from doing nothing to banning a potentially harmful substance or activity, for instance) may be justified when the degree of possible harm is large and irreversible.

mean ''learning by doing''): the design of management programs to test hypotheses about how components of an ecosystem function and interact, in order to reduce uncertainty about the system more rapidly than would otherwise occur. Under an adaptive management approach, for example, a fisheries manager might intentionally set harvest levels either lower or higher than the ''best estimate'' in order to gain information more rapidly about the shape of the yield curve for the fishery. Given the high levels of uncertainty surrounding coupled socioecological systems, the use of active adaptive management is often warranted.

Promising Responses for Ecosystem Services and Human Well-being

Past actions to slow or reverse the degradation of ecosystems have yielded significant benefits, but these improvements have generally not kept pace with growing pressures and demands. Although most ecosystem services assessed in the MA are being degraded, the extent of that degradation would have been much greater without responses implemented in past decades. For example, more than 100,000 protected areas (including strictly protected areas such as national parks as well as areas managed for the sustainable use of natural ecosystems such as timber harvest or wildlife harvest) covering about 11.7% of the terrestrial surface have now been established. These protected areas play an important role in the conservation of biodiversity and ecosystem services, although important gaps remain in their distribution and management, particularly in marine and freshwater systems. Many protected areas lack adequate resources for management. Protected areas will not be completely effective until they are fully integrated into an ecosystem or landscape approach to management. [5]

An effective set of responses to ensure the sustainable management of ecosystems would address the indirect and direct drivers that lead to the degradation of ecosystem services and overcome a range of barriers. The barriers to be overcome include:

- inappropriate institutional and governance arrangements, including the presence of corruption and weak systems of regulation and accountability;
- market failures and the misalignment of economic incentives;
- social and behavioral factors, including the lack of political and economic power of some groups (such as poor people, women, and indigenous groups) who are particularly dependent on ecosystem services or harmed by their degradation;
- underinvestment in the development and diffusion of technologies that could increase the efficiency of use of ecosystem services and reduce the harmful impacts of various drivers of ecosystem change; and
- insufficient knowledge (as well as the poor use of existing knowledge) concerning ecosystem services and management, policy, technological, behavioral, and institutional responses that could enhance benefits from these services while conserving resources.

All these barriers are compounded by weak human and institutional capacity related to the assessment and management of ecosystem services, underinvestment in the regulation and management of their use, lack of public awareness, and lack of awareness among decision-makers of the threats posed by the degradation of ecosystem services and the opportunities that more sustainable management of ecosystems could provide.

The MA assessed 78 response options for ecosystem services, integrated ecosystem management, conservation and sustainable use of biodiversity, waste management, and climate change. Many of these options hold significant promise for conserving or sustainably enhancing the supply of ecosystem services; a selected number of promising responses that address the barriers just described are discussed here. (The full list of response options is presented in Appendix R1.) These responses in turn often require that the proper enabling conditions are in place. (See Box R1.) The stakeholder groups that would need to take decisions to implement each response are indicated as follows: G for government, B for business and industry, and N for nongovernmental organizations and other civil society organizations (including community-based and indigenous peoples' organizations and research institutions).

Institutions and Governance

Changes in institutional and environmental governance frameworks are sometimes required in order to create the

BOX R1

Enabling Conditions for Designing Effective Responses

Some examples of conditions that must be met in order to design and implement some of the response options identified in this assessment include:

- *supportive insurance and financial markets* are needed to ensure that economic value of ecosystem services is taken into account;
- *better information on who benefits and is harmed by changes in specific ecosystem services* is needed to enable the establishment of effective systems of payments for ecosystem services;
- *greater involvement of concerned stakeholders in decision-making* is required to ensure transparency and effective functioning of regulatory mechanisms;
- *appropriate forms of property rights* (mostly common property arrangements) need to be established to encourage private-public or community-state partnerships for resource conservation;
- *innovative partnerships among different knowledge-based institutions* need to be established to foster the integration of local and indigenous knowledge in decision-making processes; and
- *human and institutional capacity for assessing and acting on assessments* needs to be enhanced for decision-makers to have access to information they need concerning the management of ecosystem services.

enabling conditions for effective management of ecosystems; in other cases, existing institutions could meet these needs but face significant barriers. [2, 7, 11, 12, 15, 17] Many existing institutions at both the global and the national level have the mandate to address the degradation of ecosystem services but face a variety of challenges in doing so related to the need for greater cooperation across sectors and the need for coordinated responses at multiple scales (see the discussion above on Characteristics of Successful Responses). However, since a number of the issues identified in this assessment are recent concerns and were not specifically taken into account in the design of today's institutions, changes in existing institutions and the development of new ones may sometimes be needed, particularly at the national scale.

In particular, existing national and global institutions are not well designed to deal with the management of open access resources, a characteristic of many ecosystem services. Issues of ownership and access to resources, rights to participation in decision-making, and regulation of particular types of resource use or discharge of wastes can strongly influence the sustainability of ecosystem management and are fundamental determinants of who wins and who loses from changes in ecosystems. Corruption—a major obstacle to effective management of ecosystems—also stems from weak systems of regulation and accountability.

Promising interventions include:

- *Development of institutions that devolve (or centralize) decision-making to meet management needs while ensuring effective coordination across scales* (G, B, N). Problems of ecosystem management have been exacerbated by both overly centralized and overly decentralized decision-making. For example, highly centralized forest management has proved ineffective in many countries, and efforts are now being made to move responsibility to lower levels of decision-making either within the natural resources sector or as part of broader decentralization of governmental responsibilities. At the same time, one of the most intractable problems of ecosystem management has been the lack of alignment between political boundaries and units appropriate for the management of ecosystem goods and services. Downstream communities may not have access to the institutions through which upstream actions can be influenced; alternatively, downstream communities or countries may be stronger politically than upstream regions and may dominate control of upstream areas without addressing upstream needs.
- *Development of institutions to regulate interactions between markets and ecosystems* (G). The potential of policy and market reforms to improve ecosystem management is often constrained by weak or absent institutions. For example, the potential of the Clean Development Mechanism established under the Framework Convention on Climate Change to provide financial support to developing countries in return for greenhouse gas reductions, which would realize climate and biodiversity benefits through payments for carbon sequestration in forests, is constrained by unclear property rights, concerns over the permanence of reductions, and lack of mechanisms for resolving conflicts. Moreover, existing regulatory institutions often do not have ecosystem protection as a clear mandate. For example, independent regulators of privatized water systems and power systems do not necessarily promote resource use efficiency and renewable supply. [7] The role of the state in setting and enforcing rules continues to be important even in the context of privatization and market-led growth.
- *Development of institutional frameworks that promote a shift from highly sectoral resource management approaches to more integrated approaches* (G, B). In most countries, separate ministries are in charge of various aspects of ecosystems (such as ministries of environment, agriculture, water, and forests) and drivers of change (such as ministries of energy, transportation, development, and trade). Each of these ministries has control over different aspects of ecosystem management. As a result, there is seldom the political will to develop effective ecosystem management strategies, and competition among the ministries can often result in policy choices that are detrimental to ecosystems. Integrated responses intentionally and actively address ecosystem services and human well-being simultaneously, such as integrated coastal zone management, integrated river basin management, and national sustainable development strategies. Although the potential for integrated responses is high, numerous barriers have limited their effectiveness: they are resource-intensive, but the potential benefits can exceed the costs; they require multiple instruments for their implementation; and they require new institutional and governance structures, skills, knowledge, and capacity. Integrated responses at local levels have been successful in using the links between human well-being and ecosystems to design effective interventions, particularly where supportive higher level structures exist.

Economics and Incentives

Economic and financial interventions provide powerful instruments to regulate the use of ecosystem goods and services. [2] Because many ecosystem services are not traded in markets, markets fail to provide appropriate signals that might otherwise contribute to the efficient allocation and sustainable use of the services. Even if people are aware of the services provided by an ecosystem, they are neither compensated for providing these services nor penalized for reducing them. In addition, the people harmed by the degradation of ecosystem services are often not the ones who benefit from the actions leading to their degra-

dation, and so those costs are not factored into management decisions. A wide range of opportunities exists to influence human behavior to address this challenge in the form of economic and financial instruments. Some of them establish markets; others work through the monetary and financial interests of the targeted social actors; still others affect relative prices.

Market mechanisms can only work if supporting institutions are in place, and thus there is a need to build institutional capacity to enable more widespread use of these mechanisms. [2, 6, 7, 8, 17] The adoption of economic instruments usually requires a legal framework, and in many cases the choice of a viable and effective economic intervention mechanism is determined by the socioeconomic context. For example, resource taxes can be a powerful instrument to guard against the overexploitation of an ecosystem service, but an effective tax scheme requires well-established and reliable monitoring and tax collection systems. Similarly, subsidies can be effective to introduce and implement certain technologies or management procedures, but they are inappropriate in settings that lack the transparency and accountability needed to prevent corruption. The establishment of market mechanisms also often involves explicit decisions about wealth distribution and resource allocation, when, for example, decisions are made to establish private property rights for resources that were formerly considered common pool resources. For that reason, the inappropriate use of market mechanisms can further exacerbate problems of poverty.

Promising interventions include:

- *Elimination of subsidies that promote excessive use of ecosystem services (and, where possible, transfer of these subsidies to payments for nonmarketed ecosystem services)* (G). Many countries provide significant agricultural production subsidies that lead to greater food production in countries with subsidies than global market conditions warrant; that promote the overuse of water, fertilizers, and pesticides; and that reduce the profitability of agriculture in developing countries. [7] Subsidies increase land values, adding to landowners' resistance to subsidy reductions. Similar problems are created by fishery subsidies. Although removal of production subsidies would produce net benefits, it would not occur without costs. The farmers and fishers benefiting directly from the subsidies would suffer the most immediate losses, but there would also be indirect effects on ecosystems both locally and globally. In some cases, it may be possible to transfer production subsides to other activities that promote ecosystem stewardship, such as payment for the provision or enhancement of regulatory or supporting services. Compensatory mechanisms may be needed for the poor who are adversely affected by the immediate removal of subsidies. Reduced subsidies within the OECD may lessen pressures on some ecosystems in those countries, but they could lead to more rapid conversion and intensification of land for agriculture in developing countries and would thus need to be accompanied by policies to minimize the adverse impacts on ecosystems there.
- *Greater use of economic instruments and market-based approaches in the management of ecosystem services* (G, B, N). Economic instruments and market mechanisms with the potential to enhance the management of ecosystem services include:
  - *Taxes or user fees for activities with "external" costs* (trade-offs not accounted for in the market). These instruments create incentives that lessen the external costs and provide revenues that can help protect the damaged ecosystem services. Examples include taxes on excessive application of nutrients or ecotourism user fees.
  - *Creation of markets, including through cap-and-trade systems.* Ecosystem services that have been treated as "free" resources, as is often the case for water, tend to be used wastefully. The establishment of markets for the services can both increase the incentives for their conservation and increase the economic efficiency of their allocation if supporting legal and economic institutions are in place. However, as noted earlier, while markets will increase the efficiency of the use of the resource, they can have harmful effects on particular groups of users who may be inequitably affected by the change. The combination of regulated emission caps, coupled with market mechanisms for trading pollution rights, often provides an efficient means of reducing emissions harmful to ecosystems. For example, one of the most rapidly growing markets related to ecosystem services is the carbon market [13]; in another example, nutrient trading systems may be a low-cost way to reduce water pollution in the United States [9].
  - *Payment for ecosystem services.* Mechanisms can be established to enable individuals, firms, or the public sector to pay resource owners to provide particular services. For example, in New South Wales, Australia, associations of farmers purchase salinity credits from the State Forests Agency, which in turn contracts with upstream landholders to plant trees, which reduce water tables and store carbon. Similarly, in 1996, Costa Rica established a nationwide system of conservation payments to induce landowners to provide ecosystem services. Under this program, the government brokers contracts between international and domestic "buyers" and local "sellers" of sequestered carbon, biodiversity, watershed services, and scenic beauty. These interventions are found to succeed, typically when a high degree of certainty exists with regard to the accrual of ecosystem services over time.
  - *Mechanisms to enable consumer preferences to be expressed through markets.* Consumer pressure may provide an alternative way to influence producers to adopt more sustainable production practices in the absence of effective government regulation. For example, certification schemes that exist for sustainable fisheries and forest practices provide people with the opportunity to promote sustainability through their consumer choices. Within the forest sector, forest certification has become widespread in many countries and forest conditions; thus far, however, most certified forests are in temperate regions, managed by large companies that export to northern retailers. [6] Certification and labeling is also being used at smaller scales. For example, the Salmon Safe initiative in Oregon, United States, certifies and promotes wines and other agricultural products from Oregon farms and vineyards that have adhered to management practices designed to protect water quality and salmon habitat. [7]

Social and Behavioral Responses

Social and behavioral responses—including population policy, public education, civil society actions, and empowerment of communities, women, and youth—can be instrumental in responding to ecosystem degradation. [2, 5, 6] These are generally interventions that stakeholders initiate and execute through exercising their procedural or democratic rights in efforts to improve ecosystems and human well-being.

Promising interventions include:

- *Measures to reduce aggregate consumption of unsustainably managed ecosystem services* (G, B, N). The choices about what individuals consume and how much they consume are influenced not just by considerations of price but also by behavioral factors related to culture, ethics, and values. Behavioral changes that could reduce demand for degraded ecosystem services can be encouraged through actions by governments (such as education and public awareness programs or the promotion of demand-side management), industry (such as improved product labeling or commitments to use raw materials from sources certified as sustainable), and civil society (such as public awareness campaigns). Efforts to reduce aggregate consumption, however, must sometimes incorporate measures to increase the access to and consumption of those same ecosystem services by specific groups such as poor people.
- *Communication and education* (G, B, N). Improved communication and education are essential to achieve the objectives of the environmental conventions, the Johannesburg Plan of Implementation, and the sustainable management of natural resources more generally. Both the public and decision-makers can benefit from education concerning ecosystems and human well-being, but education more generally provides tremendous social benefits that can help address many drivers of ecosystem degradation. For example, the Haribon Foundation in the Philippines has used communication, education, and mobilization of networks to motivate fishers and their communities to create marine sanctuaries to allow for fish populations to revive and restore declining catches; over 1,000 reserves have now been established. [5] Barriers to the effective use of communication and education include a failure to use research and apply modern theories of learning and change. While the importance of communication and education is well recognized, providing the human and financial resources to undertake effective work is a continuing barrier.
- *Empowerment of groups particularly dependent on ecosystem services or affected by their degradation, including women, indigenous people, and young people* (G, B, N). Women, indigenous people, and young people are all important ''stakeholders'' in the management of ecosystem services but, historically, each group has tended to be marginalized in decision-making processes. For example, despite women's knowledge about the environment and the potential they possess to improve resource management, their participation in decision-making has often been restricted by social and cultural structures. Similarly, the case for protecting young people's ability to take part in decision-making is strong as they will experience the longer-term consequences of decisions made today concerning ecosystem services. Greater involvement of indigenous peoples in decision-making can also enhance environmental management, although the primary justification for it continues to be based on human and cultural rights.

Technological Responses

Given the growing demands for ecosystem services and other increased pressures on ecosystems, the development and diffusion of technologies designed to increase the efficiency of resource use or reduce the impacts of drivers such as climate change and nutrient loading are essential. [2, 6, 7, 13, 17] Technological change has been essential for meeting growing demands for some ecosystem services, and technology holds considerable promise to help meet future growth in demand. Technologies already exist for reducing nutrient pollution at reasonable costs—including technologies to reduce point source emissions, changes in crop management practices, and precision farming techniques to help control the application of fertilizers to a field, for example—but new policies are needed for these tools to be applied on a sufficient scale to slow and ultimately reverse the increase in nutrient loading (recognizing that this global goal must be achieved even while increasing nutrient applications in relatively poor regions such as sub-Saharan Africa). Many negative impacts on ecosystems and human well-being have resulted from these technological changes, however. The cost of ''retrofitting'' technologies once their negative consequences become apparent can be extremely high, so careful assessment is needed prior to the introduction of new technologies.

Promising interventions include:

- *Promotion of technologies that increase crop yields without any harmful impacts related to water, nutrient, and pesticide use* (G, B, N). Agricultural expansion will continue to be one of the major drivers of biodiversity loss well into the twenty-first century. Development, assessment, and diffusion of technologies that could increase the production of food per unit area sustainably without harmful trade-offs related to excessive use of water, nutrients, or pesticides would significantly lessen pressure on other ecosystem services.
- *Restoration of ecosystem services* (G, B, N). Ecosystem restoration activities are now common in many countries and include actions to restore almost all types of ecosystems, including wetlands, forests, grasslands, estuaries, coral reefs, and mangroves. Ecosystems with some features of the ones that were present before conversion can often be established and can provide some of the original ecosystem services (such as pollution filtration in wetlands or timber production from forests). The restored systems seldom fully replace the original systems, but they still help meet needs for particular services. Yet the cost of restoration is generally extremely high in relation to the cost of preventing the degradation of the ecosystem. Not all services can be restored, and those that are heavily degraded may require considerable time for restoration.
- *Promotion of technologies to increase energy efficiency and reduce greenhouse gas emissions* (G, B). Significant reductions in net greenhouse gas emissions are technically feasible due to an extensive array of technologies in the energy supply, energy demand, and waste management sectors. Reducing projected emissions will require a portfolio of energy production technologies ranging from fuel switching (coal/oil to gas) and increased power plant efficiency to increased use of renewable energy technologies, complemented by more efficient use of energy in the transportation, buildings, and industry sectors. [13] It will also involve the development and implementation of supporting institutions and policies to overcome barriers to the diffusion of these technologies into the marketplace, increased public and private-sector funding for research and development, and effective technology transfer.

Knowledge and Cognitive Responses

Effective management of ecosystems is constrained both by a lack of knowledge and information concerning different aspects of ecosystems and by the failure to use adequately the information that does exist in support of management decisions. [2, 14] Although sufficient information exists to take many actions that could help conserve ecosystems and enhance human well-being, major information gaps exist. In most regions, for example, relatively little is known about the status and economic value of most ecosystem services, and their depletion is rarely tracked in national economic accounts.

At the same time, decision-makers do not use all of the relevant information that is available. This is due in part to institutional failures that prevent existing policy-relevant scientific information from being made available to decision-makers. But it is also due to the failure to incorporate other forms of knowledge and information, such as traditional knowledge and practitioners' knowledge, which are of considerable value for ecosystem management.

Promising interventions include:

- *Incorporate both the market and nonmarket values of ecosystems in resource management and investment decisions* (G, B). Most resource management and investment decisions are strongly influenced by considerations of the monetary costs and benefits of alternative policy choices. In the case of ecosystem management, however, this often leads to outcomes that are not in the interest of society, since the nonmarketed values of ecosystems may exceed the marketed values. As a result, many existing resource management policies favor sectors such as agriculture, forestry, and fisheries at the expense of the use of these same ecosystems for water supply, recreation, and cultural services that may be of greater economic value. Decisions can be improved if they include the total economic value of alternative management options and involve deliberative mechanisms that bring to bear noneconomic considerations as well.
- *Use of all relevant forms of knowledge and information in assessments and decision-making, including traditional and practitioners' knowledge* (G, B, N). Effective management of ecosystems typically requires ''place-based'' knowledge—information about the specific characteristics and history of an ecosystem. Formal scientific information is often one source of such information, but traditional knowledge or practitioners' knowledge held by local resource managers can be of equal or greater value. While that knowledge is used in the decisions taken by those who have it, it is too rarely incorporated into other decision-making processes and is often inappropriately dismissed.
- *Enhance and sustain human and institutional capacity for assessing the consequences of ecosystem change for human well-being and acting on such assessments* (G, B, N). Greater technical capacity is needed for agriculture, forest, and fisheries management. But the capacity that exists for these sectors, as limited as it is in many countries, is still vastly greater than the capacity for effective management of other ecosystem services. Because awareness of the importance of these other services has only recently grown, there is limited experience with assessing ecosystem services fully. Serious limits exist in all countries, but especially in developing countries, in terms of the expertise needed in such areas as monitoring changes in ecosystem services, economic valuation or health assessment of ecosystem changes, and policy analysis related to ecosystem services. Even when such assessment information is available, however, the traditional highly sectoral nature of decision-making and resource management makes the implementation of recommendations difficult. This constraint can also be overcome through increased training of individuals in existing institutions and through institutional reforms to build capacity for more integrated responses.

Appendix R1. Effectiveness of Assessed Responses

A response is considered to be *effective* when its assessment indicates that it has enhanced the particular ecosystem service (or, in the case of biodiversity, its conservation and sustainable use) and contributed to human well-being without significant harm to other ecosystem services or harmful impacts to other groups of people. A response is considered *promising* either if it does not have a long track record to assess but appears likely to succeed or if there are known means of modifying the response so that it can become effective. A response is considered *problematic* if its historical use indicates either that it has not met the goals related to service enhancement (or conservation and sustainable use of biodiversity) or that it has caused significant harm to other ecosystem services. Labeling a response as *effective* does not mean that the historical assessment has not identified problems or harmful trade-offs. Such trade-offs almost always exist, but they are not considered significant enough to negate the effectiveness of the response. Similarly, labeling a response as *problematic* does not mean that there are no promising opportunities to reform the response in a way that can meet its policy goals without undue harm to ecosystem services.

The typology of responses presented here is defined by the nature of intervention, classified as follows: institutional and legal (I), economic and incentives (E), social and behavioral (S), technological (T), and knowledge and cognitive (K). The actors who make decisions to implement a response are governments at different levels, such as international (GI) (mainly through multilateral agreements or international conventions), national (GN), and local (GL); the business/industry sector (B); and civil society, which includes nongovernmental organizations (NGO), community-based and indigenous peoples' organizations (C), and research institutions (R). The actors are not necessarily equally important.

The table includes responses assessed for a range of ecosystem services—food, fresh water, wood, nutrient management, flood and storm control, disease regulation, and cultural services. It also assesses responses for biodiversity conservation, integrated responses, and responses addressing one specific driver: climate change.

Response	Effectiveness			Notes	Type of Response	Required Actors
	Effective	Promising	Problematic			
Biodiversity Conservation and Sustainable Use						
Protected areas	■	■		PAs are extremely important in biodiversity and ecosystem conservation programs, especially in sensitive environments that contain valuable biodiversity components. At global and regional scales, existing PAs are essential but not sufficient to conserve the full range of biodiversity. PAs need to be better located, designed, and managed to ensure representativeness and to deal with the impacts of human settlement within PAs, illegal harvesting, unsustainable tourism, invasive species, and climate change. They also need a landscape approach that includes protection outside of PAs. [5]	I	GI GN GL NGO C R
Helping local people capture biodiversity benefits		■	■	Providing incentives for biodiversity conservation in the form of benefits for local people (e.g., through products from single species or from ecotourism) has proved to be very difficult. Programs have been more successful when local communities have been in a position to make management decisions consistent with overall biodiversity conservation. "Win-win" opportunities for biodiversity conservation and benefits for local communities exist, but local communities can often achieve greater benefits from actions that lead to biodiversity loss. [5]	E	GN GL B NGO C
Promoting better management of wild species as a conservation tool, including ex situ conservation	■			More effective management of individual species should enhance biodiversity conservation and sustainable use. "Habitat-based" approaches are critical, but they cannot replace "species-based" approaches. Zoos, botanical gardens, and other ex situ programs build support for conservation, support valuable research, and provide cultural benefits of biodiversity. [5]	T S	GN C NGO R
Integrating biodiversity into regional planning	■			Integrated regional planning can provide a balance among land uses that promotes effective trade-offs among biodiversity, ecosystem services, and other needs of society. Great uncertainty remains as to what components of biodiversity persist under different management regimes, limiting the current effectiveness of this approach. [5]	I	GN GL NGO
Encouraging private sector involvement in biodiversity conservation		■		Many companies are preparing their own biodiversity action plans, managing their landholdings in ways that are more compatible with biodiversity conservation, supporting certification schemes that promote more sustainable use, and accepting their responsibility for addressing biodiversity issues. The business case that has been made for larger companies needs to be extended to other companies as well. [5]	I	GN B NGO R
Including biodiversity issues in agriculture, forestry, and fisheries		■		More diverse production systems can be as effective as low-diversity systems, or even more effective. Strategies based on more intensive production rather than on the expansion of the area allow for better conservation. [5]	T	GN B

Response	Effectiveness			Notes	Type of Response	Required Actors
	Effective	Promising	Problematic			
Designing governance approaches to support biodiversity		■	■	Decentralization of biodiversity management in many parts of the world has had variable results. The key to success is strong institutions at all levels, with secure tenure and authority at local levels essential to providing incentives for sustainable management. [5]	I	GI GN GL R
Promoting international cooperation through multilateral environmental agreements		■		MEAs should serve as an effective means for international cooperation in the areas of biodiversity conservation and sustainable use. They cover the most pressing drivers and issues related to biodiversity loss. Better coordination between conventions would increase their usefulness. [5,15]	I	GI GN
Environmental education and communication	■			Environmental education and communication programs have both informed and changed preferences for biodiversity conservation and have improved implementation of biodiversity responses. Providing the human and financial resources to undertake effective work in this area is a continuing challenge. [5]	S	GN GL NGO C
Food						
Globalization, trade, and domestic and international policies on food		■	■	Government policies related to food production (price supports and various types of payments, or taxes) can have adverse economic, social, and environmental effects. [6]	E	GI GN B
Knowledge and education	■	■		Further research can make food production socially, economically, and environmentally sustainable. Public education should enable consumers to make informed choices about nutritious, safe, and affordable food. [6]	S K	GN GL NGO C
Technological responses, including biotechnology, precision agriculture, and organic farming		■		New agricultural sciences and effective natural resource management could support a new agricultural revolution to meet worldwide food needs. This would help environmental, economic, and social sustainability. [6]	T	GN B R
Water management		■		Emerging water pricing schemes and water markets indicate that water pricing can be a means for efficient allocation and responsible use. [6]	E	GN GL B NGO
Fisheries management		■	■	Strict regulation of marine fisheries is needed, both regarding the establishment and implementation of quotas and steps to address unreported and unregulated harvest. Individual transferable quotas also show promise for cold water, single-species fisheries, but they are unlikely to be useful in multispecies tropical fisheries. Given the potential detrimental environmental impacts of aquaculture, appropriate regulatory mechanisms need to supplement existing policies. [6]	I E	GN GL B NGO

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	Effective	Promising	Problematic			
Livestock management				Livestock policies need to be reoriented in view of problems concerning overgrazing and dryland degradation, rangeland fragmentation and loss of wildlife habitat, dust formation, bush encroachment, deforestation, nutrient overload through disposal of manure, and greenhouse gas emissions. Policies also need to focus on human health issues related to diseases such as bird flu and BSE. [6]	T	GN B
Recognition of gender issues				Response policies need to be gender-sensitive and designed to empower women and ensure access to and control of resources necessary for food security. This needs to be based on a systematic analysis of gender dynamics and explicit consideration of relationships between gender and food and water security. [6]	S	GN NGO C
Fresh Water						
Determining ecosystem water requirements				In order to balance competing demands, it is critical that society explicitly agrees on ecosystem water requirements (environmental flows). [7]	I T	GN GL NGO R
Rights to freshwater services and responsibilities for their provision				Both public and private ownership systems of fresh water, and of the land resources associated with its provision, have largely failed to create incentives for provision of water services. As a result, upland communities have generally been excluded from access to benefits, particularly when they lack tenure security, and have resisted regulations regarded as unfair. Effective property rights systems with clear and transparent rules can increase stakeholders' confidence that they will have access to the benefits of freshwater services and, therefore, willingness to pay for them. [7]	I	GN B C
Increasing the effectiveness of public participation in decision-making				Degradation of freshwater and other ecosystem services has a disproportionate impact on those excluded from participation in decision-making. Key steps for improving participatory processes are to increase the transparency of information, improve the representation of marginalized stakeholders, engage them in the establishment of policy objectives and priorities for the allocation of freshwater services, and create space for deliberation and learning that accommodates multiple perspectives. [7]	I	GN GL NGO C R
River basin organizations				RBOs can play an important role in facilitating cooperation and reducing transaction costs of large-scale responses. RBOs are constrained or enabled primarily by the degree of stakeholder participation, their agreement on objectives and management plans, and their cooperation on implementation. [7]	I	GI GN NGO

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	Effective	Promising	Problematic			
Regulatory responses	■			Regulatory approaches based on market-based incentives (e.g., damages for exceeding pollution standards) are suitable for point-source pollutants. Regulatory approaches that simply outlaw particular types of behavior can be unwieldy and burdensome, and may fail to provide incentives for protecting freshwater services. [7]	I	GN GL
Water markets		■		Economic incentives can potentially unlock significant supply- and demand-side efficiencies while providing cost-effective reallocation between old (largely irrigation) and new (largely municipal and instream) uses. [7]	E	GI GN B
Payments for watershed services		■		Payments for ecosystem services provided by watersheds have narrowly focused on the role of forests in the hydrological regime. They should be based on the entire flow regime, including consideration of the relative values of other land cover and land uses, such as wetlands, riparian areas, steep slopes, roads, and management practices. Key challenges for payment schemes are capacity-building for place-based monitoring and assessment, identifying services in the context of the entire flow regime, considering trade-offs and conflicts among multiple uses, and making uncertainty explicit. [7]	E	GN B C
Partnerships and financing		■	■	There is a clear mismatch between the high social value of freshwater services and the resources allocated to manage water. Insufficient funding for water infrastructure is one manifestation of this. Focusing only on large-scale privatization to improve efficiency and cost-recovery has proven a double-edged strategy—price hikes or control over resources have created controversy and, in some cases, failure and withdrawal. Development of water infrastructure and technologies must observe best practices to avoid problems and inequities. The re-examination and retrofitting/refurbishment of existing infrastructure is the best option in the short and medium term. [7]	I E	GI GN B NGO C
Large dams			■	The impact of large dams on freshwater ecosystems is widely recognized as being more negative than positive. In addition, the benefits of their construction have rarely been shared equitably—the poor and vulnerable and future generations often fail to receive the social and economic benefits from dams. Pre-construction studies are typically overly optimistic about the benefits of projects and underestimate costs. [7]	T	GN
Wetland restoration		■		Although wetland restoration is a promising management approach, there are significant challenges in determining what set of management interventions will produce a desired combination of wetland structure and function. It is unlikely that created wetlands can structurally and functionally replace natural wetlands. [7]	T	GN GL NGO B

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	Effective	Promising	Problematic			
Wood, Fuelwood, and Non-wood Forest Products						
International forest policy processes and development assistance	■			International forest policy processes have made some gains within the forest sector. Attention should be paid to integration of agreed forest management practices in financial institutions, trade rules, global environment programs, and global security decision-making. [8]	I	GI GN B
Trade liberalization		■	■	Forest product trade tends to concentrate decision-making power on (and benefits from) forest management, rather than spreading it to include poorer and less powerful players. It "magnifies" the effect of governance, making good governance better and bad governance worse. Trade liberalization can stimulate a "virtuous cycle" if the regulatory framework is robust and externalities are addressed. [8]	E	GI GN
National forest governance initiatives and national forest programs		■		Forest governance initiatives and country-led national forest programs show promise for integrating ecosystem health and human well-being where they are negotiated by stakeholders and strategically focused. [8]	I	GN GL
Direct management of forests by indigenous peoples		■		Indigenous control of traditional homelands is often presented as having environmental benefits, although the main justification continues to be based on human and cultural rights. Little systematic data exist, but preliminary findings on vegetation cover and forest fragmentation from the Brazilian Amazon suggest that an indigenous-control area can be at least as effective as a strict-use protected area. [8]	I	GL C
Collaborative forest management and local movements for access and use of forest products		■	■	Government–community collaborative forest management can be highly beneficial but has had mixed results. Programs have generated improved resource management and access of the rural poor to forest resources, but have fallen short in their potential to benefit the poor. Local responses to problems of access and use of forest products have proliferated in recent years. They are collectively more significant than efforts led by governments or international processes but require their support to spread. [8]	I	GN GL B NGO C
Small-scale private and public-private ownership and management of forests		■		Small-scale private ownership of forests can deliver more local economic benefits and better forest management than ownership by larger corporate bodies where information, tenure, and capacity are strong. [8]	I	GL B C
Company–community forestry partnerships		■		Company–community partnerships can be better than solely corporate forestry, or solely community or small-scale farm forestry, in delivering benefits to the partners and the public at large. [8]	I	GL B C

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Public and consumer action	■			Public and consumer action has resulted in important forest and trade policy initiatives and improved practices in large forest corporations. This has had an impact in "timber-consuming countries" and in international institutions. The operating standards of some large corporations and institutions, as well as of those whose non-forest activities have an impact on forests, have been improved. [8]	S	NGO B C
Third-party voluntary forest certification		■		Forest certification has become widespread; however, most certified forests are in industrial countries, managed by large companies and exporting to Northern retailers. The early proponents of certification hoped it would be an effective response to tropical deforestation. [8]	I E	B
Wood technology and biotechnology		■		Wood technology responses have focused on industrial plantation species with properties suited for manufactured products. [8]	T	GN R B
Commercialization of non-wood forest products		■	■	Commercialization of NWFP has had modest impacts on local livelihoods and has not always created incentives for conservation. An increased value of NWFPs is not always an incentive for conservation and can have the opposite effect. Incentives for sustainable management of NWFPs should be reconsidered, including exploration of joint production of timber and NWFP. [8]	E	NGO B R
Natural forest management in the tropics		■		To be economic, sustainable natural forest management in the tropics must focus on a range of forest goods and services, not just timber. The "best practices" of global corporations should be assessed, exploring at the same time "what works" in traditional forest management and the work of local (small) enterprises. Considerable interest has developed in the application of reduced impact logging, especially in tropical forests, which lowers environmental impacts and can also be more efficient and cost effective. [8]	T	GI GN GL B NGO C
Forest plantation management		■	■	Farm woodlots and large-scale plantations are increasingly being established in response to growing wood demand and declining natural forest areas. Without adequate planning and management, forest plantations can be established in the wrong sites, with the wrong species and provenances. In degraded lands, afforestation may deliver economic, environmental, and social benefits to communities and help in reducing poverty and enhancing food security. [8]	T	GN GL B NGO R
Fuelwood management		■		Fuelwood remains one of the main products of the forest sector in developing countries. If technology development continues, industrial-scale forest product fuels could become a major sustainable energy source. [8]	T	GL B C

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	Effective	Promising	Problematic			
Afforestation and reforestation for carbon management		■		Although many early initiatives were based on forest conservation or management, afforestation activities now predominate, perhaps reflecting the international decisions in 2001 to allow only afforestation and reforestation activities into the Clean Development Mechanism for the first commitment period. [8]	T E	GI GN B
Nutrient Cycling						
Regulations		■	■	Mandatory policies, including regulatory control and tax or fee systems, place the costs and burden of pollution control on the polluter. Technology-based standards are easy to implement but may discourage innovation and are generally not seen as cost-effective. [9]	I	GI GN
Market-based instruments		■		Market-based instruments, such as financial incentives, subsidies, and taxes, hold potential for better nutrient management, but may not be relevant in all countries and circumstances. Relatively little is known empirically about the impact of these instruments on technological change. [9]	E	GN B R
Hybrid approaches		■		Combinations of regulatory, incentive, and market-based mechanisms are possible for both national and watershed-based approaches and may be the most cost-effective and politically acceptable. [9]	I E	GI GN GL NGO C R
Flood and Storm Regulation						
Physical structures			■	Historically, emphasis was on physical structures/measures over natural environment and social institutions. This choice often creates a false sense of security, encouraging people to accept high risks. Evidence indicates that more emphasis needs to be given to the natural environment and nonstructural measures. [11]	T	GN B
Use of natural environment	■			Flood and storm impacts can be lessened through maintenance and management of vegetation and through natural or human-made geomorphological features (natural river channels, dune systems, terrace farming). [11]	T	GN GL NGO C
Information, institutions, and education	■			These approaches, which emphasize disaster preparedness, disaster management, flood and storm forecasting, early warning, and evacuation, are vital for reducing losses. [11]	S I	GN GL B C
Financial services		■	■	These responses emphasize insurance, disaster relief, and aid. Both social programs and private insurance are important coping mechanisms for flood disaster recovery. They can, however, inadvertently contribute to community vulnerability by encouraging development within floodplains or by creating cultures of entitlement. [11]	E	GN B

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Land use planning		■		Land use planning is a process of determining the most desirable type of land use. It can help to mitigate disasters and reduce risks by avoiding development in hazard prone areas. [11]	I	GN
Disease Regulation						
Integrated vector management		■		Reducing the transmission of infectious diseases often has effects on other ecosystem services. IVM enables a coordinated response to health and the environment. It uses targeted interventions to remove or control vector breeding sites, disrupt vector lifecycles, and minimize vector-human contact, while minimizing effects on other ecosystem services. IVM is most effective when integrated with socioeconomic development. [12]	I	GN NGO
Environmental management/ modification to reduce vector and reservoir host abundance		■		Environmental management interventions can be highly cost-effective and entail very low environmental impacts. [12]	I	GN B C R
Biological control/natural predators	■			Biological interventions can be highly cost-effective and entail very low environmental impacts. Biological control may be effective if breeding sites are well known and limited in number, but less feasible where these are numerous. [12]	T	GN B R
Chemical control			■	Insecticides remain an important tool and their selective use is likely to continue within IVM. However, there are concerns regarding the impacts of insecticides, especially persistent organic pollutants, on the environment and on human populations, particularly insecticide sprayers. [12]	T	GN B R
Human settlement patterns	■			The most basic management of human-vector contact is through improvements in the placement and construction of housing. [12]	T	GN NGO C
Health awareness and behavior	■			Social and behavioral responses can help control vector-borne disease while also improving other ecosystem services. [12]	S	C
Genetic modification of vector species to limit disease transmission			■	New "cutting-edge" interventions, such as transgenic techniques, could be available within the next 5–10 years. However, consensus is lacking in the scientific community on the technical feasibility and public acceptability of such an approach. [12]	T	GN B NGO R
Cultural Services						
Awareness of the global environment and linking local and global institutions	■			Awareness of the planet working as a system has led to an integrated approach to ecosystems. This process has emphasized the "human environment" concept and the discussion of environmental problems at a global scale. Local organizations also take advantage of emerging global institutions and conventions to bring their case to wider political arenas. [14]	S I	GI GN GL

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	Effective	Promising	Problematic			
From restoring landscapes to valuing cultural landscapes		■		Landscapes are subject to and influenced by cultural perceptions and political and economic interests. This influences decisions on landscape conservation. [14]	S K	GL NGO C
Recognizing sacred areas	■	■		While linking sacred areas and conservation is not new, there has been an increase in translating "the sacred" into legislation or legal institutions granting land rights. This requires extensive knowledge about the link among the sacred, nature, and society in a specific locale. [14]	S	GL NGO C
International agreements and conservation of biological and agropastoral diversity		■		Increased exploitation and awareness concerning the disappearance of local resources and knowledge has highlighted the need to protect local and indigenous knowledge. Some countries have adopted specific laws, policies, and administrative arrangements emphasizing the concept of prior informed consent of knowledge-holders. [14]	I	GI GN
Integrating local and indigenous knowledge		■	■	Local and indigenous knowledge evolves in specific contexts and good care should be taken to not de-contextualize it. Conventional "best-practices" methods focusing on content may not be appropriate to deal with local/indigenous knowledge. [14]	K I	GN B NGO
Compensating for knowledge		■		Compensation for the use of local and indigenous knowledge by third parties is an important, yet complicated response. The popular idea that local and indigenous knowledge can be promoted by strengthening "traditional" authorities may not be valid in many cases. [14]	E K	GN B C
Property right changes		■	■	Communities benefit from control over natural resources but traditional leadership may not always be the solution. Local government institutions that are democratically elected and have real authority over resources in some cases may be a better option. There is a tendency to shift responsibilities back and forth between "traditional" authorities and local government bodies, without giving any of them real decision-making powers. [14]	I	GN GL C
Certification programs		■		Certification programs are a promising response, but many communities do not have access to these programs or are not aware of their existence. In addition, the financial costs involved reduce the chances for local communities to participate independently. [14]	I S	GI GN B
Fair trade		■		Fair trade is a movement initiated to help disadvantaged or politically marginalized communities by paying better prices and providing better trading conditions, along with raising consumers' awareness of their potential role as buyers. Fair trade overlaps in some cases with initiatives focusing on the environmental performance of trade. [14]	E S	GI GN GL NGO C

Response	Effectiveness			Notes	Type of Response	Required Actors
	Effective	Promising	Problematic			
Ecotourism and cultural tourism		■		Ecotourism can provide economic alternatives to converting ecosystems; however, it can generate conflicts in resource use and the aesthetics of certain ecosystems. Different ecosystems are subjected to different types and scales of impact from tourism infrastructure. Furthermore, some ecosystems are easier to market to tourists than others. The market value of ecosystems may vary according to public perceptions of nature. Freezing of landscapes, conversion of landscapes, dispossession, and removing of human influences may result, depending on views of what ecotourism should represent. Yet when conservation receives no budgetary subsidy, tourism can provide revenues for conservation. [14]	E	GL B C
Integrated Responses						
International environmental governance		■		Environmental policy integration at the international level is almost exclusively dependent on governments' commitment to binding compromises on given issues. Major challenges include reform of the international environmental governance structure and coherence among international trade and environment mechanisms. [15]	I E K T B	GI GN
National action plans and strategies aiming to integrate environmental issues into national policies		■		Examples include national conservation strategies, national environmental action plans, and national strategies for sustainable development. Success depends on enabling conditions such as ownership by governments and civil society, broad participation, both across sectors within the government and with the private sector, and at the sub-national and local scales. National integrated responses may be a good starting point for cross-departmental linkages in governments. [15]	I E K T	GN GL B NGO C
Sub-national and local integrated approaches	■	■		Many integrated responses are implemented at the sub-national level; examples include sustainable forest management, integrated coastal zone management, integrated conservation and development programs, and integrated river basin management. Results so far have been varied, and a major constraint experienced by sub-national and multiscale responses is the lack of implementation capacity. [15]	I E K T	GN GL NGO C
Waste Management						
Technologies for waste reduction, re-use, recovery, and disposal	■			These practices have enhanced ecosystem services, improved aesthetic conditions, restored habitats for human use and for biodiversity, increased public health and well-being, created jobs, and reduced poverty. [10]	T	GN GL B C
Compliance with waste management laws and regulations		■		Communities and industries are willing to comply with laws and regulations if there is clear understanding of the benefits and if all stakeholders are involved in the formulation of such laws. [10]	L	GN GL

Response	Effectiveness			Notes	Type of Response	Required Actors
	Effective	Promising	Problematic			
Environmental awareness and education		■		Environmental awareness and education have succeeded in allowing consumers and resource users to make informed choices for minimizing waste. Employers have introduced programs to encourage communities to reduce waste. [10]	S	GL C B
Indicators and monitoring		■	■	Industries and governments need to select indicators and standardize methods to monitor the sources, types, and amounts of all wastes produced. The practice of transparent, participatory, and accountable decision-making for ecosystem sustainability and human well-being is lacking in many countries. [10]	S	GN B NGO
Climate Change						
U.N. Framework Convention on Climate Change and Kyoto Protocol		■	■	The ultimate goal of the UNFCCC is stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. The Kyoto Protocol contains binding limits on greenhouse gas emissions on industrialized countries that agreed to reduce their emissions by an average of about 5% between 2008 and 2012 relative to the levels emitted in 1990. [13]	I	GI GN
Reductions in net greenhouse gas emissions		■		Significant reductions in net greenhouse gas emissions are technically feasible, in many cases at little or no cost to society. [13]	T	GN B C
Land use and land cover change		■		Afforestation; reforestation; improved forest, cropland, and rangeland management; and agroforestry provide opportunities to increase carbon uptake, and slowing deforestation reduces emissions. [13]	T	GN GL B NGO C
Market mechanisms and incentives		■		The Kyoto Protocol mechanisms, in combination with national and regional ones, can reduce the costs of mitigation for developed countries. In addition, countries can reduce net costs of emissions abatement by taxing emissions (or auctioning permits) and using the revenues to cut distortion taxes on labor and capital. In the near term, project-based trading can facilitate the transfer of climate-friendly technologies to developing countries. [13]	E	GI GN B
Adaptation		■		Some climate change is inevitable and ecosystems and human societies will need to adapt to new conditions. Human populations will face the risk of damage from climate change, some of which may be countered with current coping systems; others may need radically new behaviors. Climate change needs to be factored into current development plans. [13]	I	GN GL NGO C R