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Ecosystems and Human Well-being: Multiscale Assessments, Volume 4

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Findings of the Sub-global Assessments Working Group
of the Millennium Ecosystem 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 to also 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.

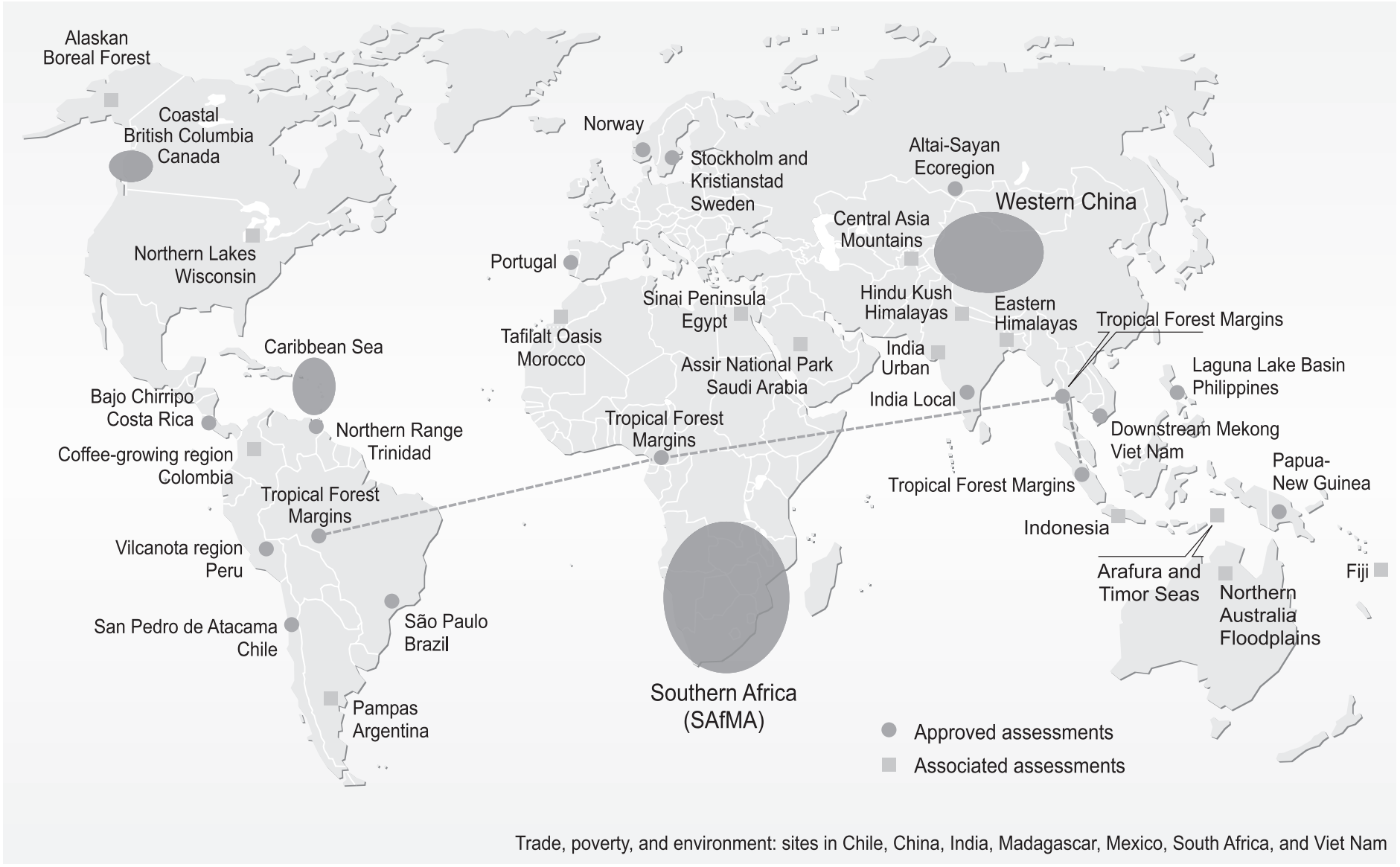
The conceptual framework for the MA posits that people are integral parts of ecosystems and that a dynamic interaction exists between them and other parts of ecosystems, with the changing human condition driving, both directly and indirectly, changes in ecosystems and thereby causing changes in human 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

The Sub-global Working Group dedicates this volume to the memory of our friend and colleague, Dr. Gerhard Petschel-Held, who was an outstanding scientist and an exceptional human being. We are grateful for his friendship and contributions to the Millennium Ecosystem Assessment.

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 Sub-global Assessment Working Group and summarizes lessons learned from the local, watershed, national, and regional assessments that were undertaken as part of the MA process. 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.

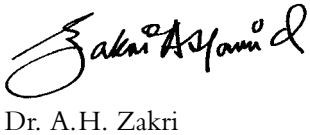
This is one of four volumes (*Current State and Trends, Scenarios, Policy Responses,* and *Multiscale Assessments*) that present the technical findings of the Assessment. Six synthesis reports have also been published: one for a general audience and others focused on issues of biodiversity, wetlands 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 Sub-global Assessment Working Group Technical Support Unit for their dedication in coordinating the production of this volume, as well as the WorldFish Center, which housed this TSU.

We would particularly like to thank the Co-chairs of the Sub-global Assessment Working Group, Dr. Doris Capistrano and Dr. Cristián Samper, and the TSU Coordinators, Marcus Lee and Ciara Raudsepp-Hearne, for their skillful leadership of this working group and their contributions to the overall assessment.

Dr. Robert T. Watson
MA Board Co-chair
Chief Scientist, The World Bank



Dr. A.H. Zakri
MA Board Co-chair
Director, Institute for Advanced Studies,
United Nations University

Preface

This report presents an overview, synthesis, and analysis of the sub-global assessments that are part of the MA, and is based on information and results obtained through December 2004. It is important to note that a number of these assessments are still at the early stages, and a full set of results will not be available for another year or two. That said, a few assessments have now been completed and many interesting results are emerging from both these and on-going assessments. Recognizing the limitations of the challenging process that the MA Sub-global Working Group has undergone, this volume presents results from that process as a contribution to the set of core MA technical assessment reports. The sources of information that have been drawn on by the authors of this report are accordingly varied, reflecting the diverse nature and processes of the sub-global assessments (see Chapter 2, Box 2.1). To a limited extent, reference has also been made to relevant assessments at sub-global scales that were not directly involved in the MA process.

The MA sub-global assessments offer valuable insights and lessons on multidisciplinary, integrated, multiscale assessments attempting to respond to diverse needs of multiple stakeholders. This report was thus produced by the MA Sub-global Working Group not only to present a preliminary analysis of findings, but also to share lessons learned on the assessment process. This report serves to assist those sub-global assessments that are at the early stages of development, as well as other interested parties intending to undertake similar assessments of their own, to overcome some of the challenges they may encounter in designing and implementing their assessments.

The first chapters in this volume present the basic concepts on which the entire MA exercise was built, with particular reference to the design of the sub-global assessments. **Chapter 1** summarizes the MA Conceptual Framework, published in 2003. **Chapter 2** supplies the background information on the start-up and execution of the sub-global assessments, as well as on the Sub-global Working Group as a whole. **Chapter 3** presents an overview of the links between ecosystem services and human well-being found in the MA sub-global assessments. **Chapter 4** presents some of the basic concepts for conducting multiscale assessments and analyzes the choice of spatial and temporal scales in the different studies, along with the effects this had on the assessment process. **Chapter 5** offers a discussion on bridging different systems of knowledge and explores how the MA has encouraged the incorporation of multiple worldviews into the assessments and what the actual experience of various sub-global assessments with this has been. This is followed by an analysis of the assessment process in **Chapter 6,** which compares the different methods used for user engagement, governance, capacity-building, and communication with the users about both the process and assessment results.

The volume then turns to an analysis of key findings of, and patterns observed in, the sub-global assessments, based on the MA conceptual framework components assessed at the sub-global level. These include analysis of direct and indirect drivers of change (**Chapter 7**), conditions and trends (**Chapter 8**), response options (**Chapter 9**), and scenarios (**Chapter 10**). These are followed by a chapter on community assessments (**Chapter 11**), which reviews the MA sub-global findings from the perspective of community assessments and offers additional insights garnered from work at that level. The volume concludes by reflecting on the MA sub-global process and offers some important lessons and recommendations for future assessment work (**Chapter 12**).

The multiscale approach is one of the most innovative aspects of the MA, and this volume presents a synthesis of perspectives from multiple scales on ecosystems, the services they provide, and the consequences of change in service provision for human well-being. The sub-global assessment process includes a wide range of case studies from across the globe, from small tourism-reliant islands in the Caribbean to traditional mountain communities in the Andes, from small villages in India to large cities in Europe. Each of these studies was led by a local or national institution interested in using and adapting the MA framework, and we recognize that there are important ecosystems, services, and regions of the world that are not adequately represented.

We believe the strength of this process lies in the diversity of ecosystems and approaches presented in this volume. We have made an effort to combine conceptual analysis of the findings and process of the sub-global assessments with illustrative examples from the sub-global assessments throughout the various chapters. We believe that there is much to be gained from the insights and lessons drawn from emerging patterns and conclusions that are common, or indeed divergent, across the sub-global assessments analyzed.

Acknowledgments

This report was the result of a broad and unique collaboration among members of the MA sub-global assessment teams and a smaller number of independent scientists whose perspectives as authors complemented those of the sub-global assessments. Each sub-global assessment in turn was the collective effort of researchers, users and stakeholders, reviewers, donors, and other supporters. We would like to acknowledge the contributions of all of the authors of this book, and the support provided by their institutions that enabled their participation. We thank all of the individuals who were involved in the sub-global assessments around the world. In particular, we wish to acknowledge the efforts of the coordinators of each sub-global assessment, and the intellectual contributions of Adel Abdel-Kader, Steve Carpenter, Angela Cropper, Owen Cylke, Mai Trong Thong, Anatoliy Mandych, Signe Nybo, Robert Prescott-Allen, Dagmar Timmer, and Joeli Veitayaki.

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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 provides brief summaries of the sub-global assessments. Appendix C lists all the authors who contributed to this volume. Appendix D lists the acronyms and abbreviations used in this report and Appendix E 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: Multiscale Assessments, Volume 4

Summary: Integrated Assessments at Multiple Scales

CONTENTS

1. What Are the MA Sub-global Assessments?

The MA, which focused on ecosystem change and the impacts of such change on human well-being, included a set of sub-global assessments at multiple spatial scales, in addition to the global assessment. This was one of the innovations of the MA compared to other international assessments, which usually focus on global or regional scales alone. The global and sub-global assessments analyzed ecosystem services and human well-being from different perspectives and with different stakeholders involved. The MA sub-global assessments were led by institutions and individuals in those countries where the sub-global assessments were carried out.

The MA sub-global assessments were conceived as integrated assessments to analyze the relationship between direct and indirect drivers of ecosystem change, their impact on ecosystem services, and the consequences for human well-being. They were also designed to compare different spatial scales, involve a diverse set of stakeholders, and use different knowledge systems as part of the assessment process. This volume presents an overview of the main outcomes and conclusions from this process, with reflections on the lessons learned.

The MA design for sub-global assessments was intended to develop and test methodologies for multiscale assessments, meet the information needs of decision-makers at every scale, and build capacity to undertake such assessments. The initial approach taken was to develop sets of nested, multiscale assessments in selected regions of the world, complemented by a ''cross-cutting'' assessment of similar ecosystems in different locations and an ''outlier'' assessment in an ecosystem or region not otherwise represented. As the process developed, however, a bottom-up approach was adopted, backed by an open call for proposals and a set of selection criteria related to assessment design and stakeholder engagement. Many sub-global assessments were established where demand and interest in such assessments arose. This resulted in a globally diverse set of assessments that were driven by user demand but did not represent a comprehensive selection or uniform sampling of ecosystems and locations around the world. [2]

The MA process included a total of 34 sub-global assessments from around the world. These assessments analyzed the importance of ecosystem services for human well-being at local, national, and regional scales. The areas covered in these assessments ranged from small villages in India, to cities like Kristianstad (Sweden) and São Paulo (Brazil), to whole countries like Portugal, and large regions like southern Africa. (See Figure SG1.) A short overview of each of the assessments involved is presented in Appendix B of this volume, and additional information is available on the MA website.

The MA design called for sub-global assessments covering multiple nested scales. For example, the Southern Africa sub-global assessment (SAfMA) included assessments of the entire region of Africa south of the equator, of the Gariep and Zambezi river basins in that region, and of local communities within those basins. (See Figure SG2.) This nested design was part of the overall design of the MA to analyze the importance of scale on ecosystem services and human well-being and to study cross-scale interactions. However, most sub-global assessments were conducted at a single spatial scale, with some multiscale analysis. [2, 4]

The sub-global assessments included a diversity of ecosystems. Examples include drylands in Chile and western China; tropical rainforests in the Amazon, Central Africa, and Southeast Asia; coastal and marine ecosystems in the Caribbean Sea and Papua New Guinea, and urban ecosystems in Sweden and Brazil, among others. Many assessments analyzed several ecosystems within a single study area. The majority of assessments (26 out of 34) included forests, inland water, or cultivated systems, which were the systems most commonly assessed. Island, coastal, and marine systems were not as widely represented (11 out of 34 assessed at least one of those systems), nor were urban systems (5 out of 34). Polar systems were not covered. [2]

The sub-global assessments involved a diversity of stakeholders in their processes, including local, regional and national governments, nongovernmental organizations, local communities, research and academic institutions, and, to a lesser extent, the private sector and international organizations. The institutions leading the assessments were different across assessments, but they were often academic or research institutions. Including a diversity of stakeholders is considered essential for effective assessments, as it enhances stakeholder ownership of the outcomes. [6]

2. What Did We Learn?

Ecosystem services are important for many dimensions of human well-being, some of which are best observed at sub-global scales.

People everywhere in the world rely on ecosystems for their well-being. The sub-global assessments provided many examples, at all scales, from local to global; in all parts of the world, from the least to the most developed; and for all peoples, from the poorest to the wealthiest, from the most rural to the most urban. Some ecosystems provide direct benefits for people: forest dwellers in Papua New Guinea harvest foods from the rainforest, fishermen in Trinidad harvest fish from the ocean, local populations in Viet Nam use plant species for medicinal purposes, and villagers in Zambia rely on wood for a variety of needs. (See Box SG1.) In other cases, the benefits from ecosystems come from regulating services essential to human well-being. Evidence suggests that the people of São Paulo, Brazil, benefit from the surrounding belt of forest that regulates both the temperature and the quality of the air in the city. The wetlands in Kristianstad, Sweden, have an important function in buffering the local population from annual flooding events. Ecosystems can also provide important cultural and spiritual services for local communities in both rural and urban settings. [3]

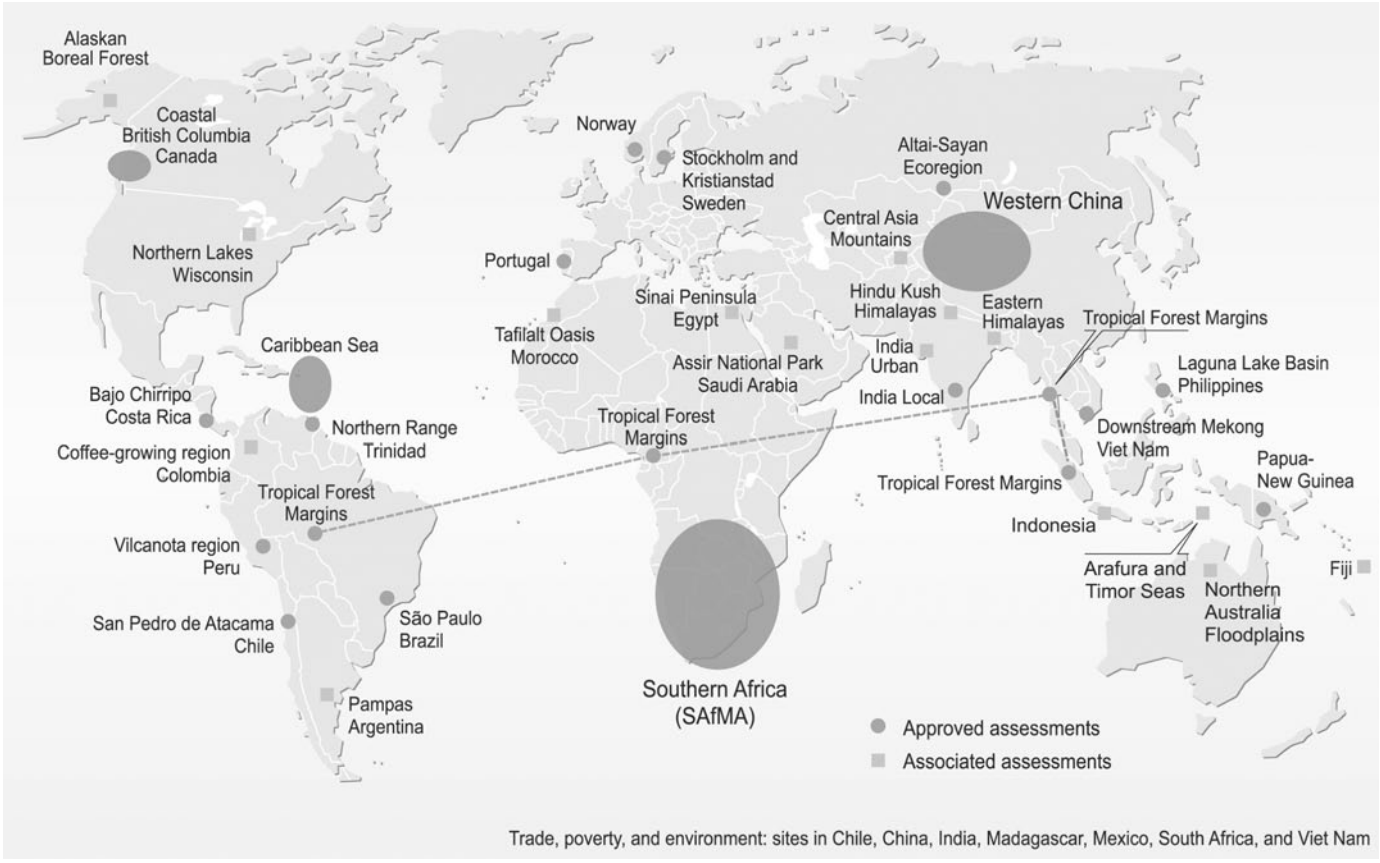

Figure SG1. Map Showing the Global Distribution of Sub-global Assessments that were Part of the Millennium Ecosystem Assessment (MA). The approved assessments were formally approved by the MA Board and followed all the guidelines of the MA, including an analysis of all components of the conceptual framework. Associated assessments used the conceptual framework, but did not necessarily analyze all components.

Spiritual and cultural services are regarded as important ecosystem services at local scales, for wealthy as well as for poor communities and in both rural and urban settings. Several assessments conducted with and by local communities highlighted the importance of spiritual and cultural services. For example, local villages in India preserve selected sacred groves of forest for spiritual reasons. Urban parks provide important cultural and recreational services in cities around the world, such as in Stockholm, where the principal urban park receives some 15 million visits every year. (See Box SG2.) [3]

There are clear trade-offs among ecosystem services; the nature of these trade-offs are context-specific and differ across assessments. The analyses performed by the sub-global assessments, in agreement with the global results, generally show an increase in provisioning services over time, at the expense of regulating services, supporting services, and biodiversity. For example, deforestation caused by increased local demand for wood resulted in an increase in human disease in India (see Box SG3), and mining and tourism activities in San Pedro de Atacama in Chile have had an impact on the availability and access to water by local populations. [3]

The relationship between ecosystem services and human well-being can take on several different forms. The sub-global assessments found a wide range of relationships between ecosystem services and human well-being. Often, rising incomes are initially accompanied by declines in some ecosystem services. In the assessment of the downstream Mekong wetlands in Viet Nam, for example, economic growth from agricultural expansion has improved human well-being, but at the expense of soil quality. Once a sufficient level of wealth is achieved, societal priorities may emphasize the quality of the environment and the services it delivers. This was most obvious in the assessment of the Stockholm Urban Park, Sweden, where stakeholders are minimizing the impacts of urban sprawl. In some cases, there is no evidence for such a turnaround, and some services may decline continuously with increasing wealth. For instance, water as a provisioning service continues to be degraded in the wealthy, urban area of Gauteng in South Africa. In yet other cases, a particular service may possibly improve continuously in tandem with increasing wealth, which would be the case in Viet Nam if increasing agricultural production were managed sustainably. The sub-global assessments did not equate human well-being with wealth, but wealth was an important and frequently measured component of well-being. [3]

In places where there are no social safety nets, diminished human well-being tends to increase im-

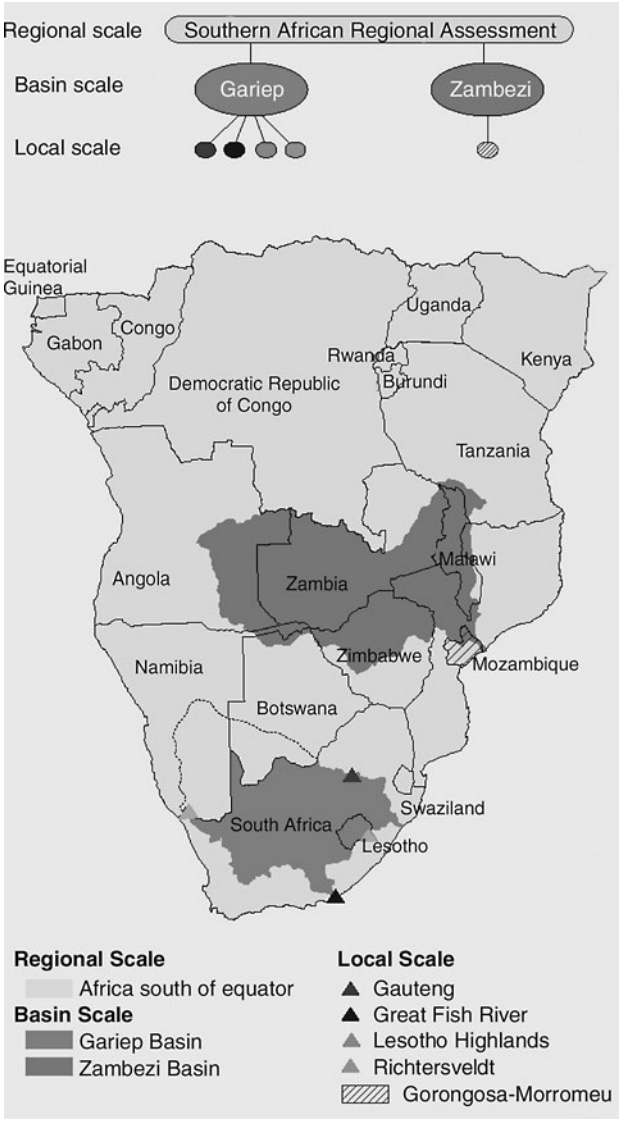

Figure SG2. The Multiscale Assessment in Southern Africa and its Nested Design. The assessment consisted of a regional component which included all countries in Africa south of the equator, basin assessments of the Gariep and Zambezi rivers, and five local assessments within those basins.

BOX SG1

Fuelwood, Water, and Health in Zambia

In the Kafue basin of Zambia, wood constitutes 96% of household energy consumption. Shortage of wood fuel occurs in areas with high population density without access to alternative and affordable energy sources. In those provinces of Zambia where population densities exceed the national average of 13.7 persons per square kilometer, the demand for wood has already surpassed local supply. In such areas, people are vulnerable to illness and malnutrition because it is too expensive to heat homes, not possible to cook food, and consumption of unboiled water facilitates the spread of waterborne diseases such as cholera. Women and children in rural poor communities are the most affected by wood fuel scarcity. They must walk long distances searching for firewood, and therefore have less time for tending crops, cooking meals, or attending school.

BOX SG2

Recreation in Urban Parks in Sweden

The National Urban Park in Stockholm, Sweden, receives 15 million visitors per year, most of whom visit the park for recreational purposes. More than 90% of the urban population in Stockholm visits the city's green area at least once a year, and about half of those visit at least weekly. Recreation in this park system promotes physical exercise and mental well-being. The green area allows humans to come into contact with nature and provides a resource for natural science teaching.

BOX SG3

Deforestation and Human Disease in India

In Koyyur village, India, deforestation has resulted in increased human disease. Growing demand for wood and other forest products caused an increase in canopy gaps in the rainforest, which allowed more sunlight to reach the forest floor. The resulting increased growth of grasses and other fodder species attracted cattle from the villages. These cattle carry ticks that transmit a monkey fever (Kyasanur forest disease) that affects people, resulting in an increase in the disease in humans.

mediate dependence on ecosystem services. The resultant additional pressure can damage the capacity of those local ecosystems to deliver services, and this capacity can decline to such a degree that the probability of disaster or conflict increases. For example, rural communities in the former tribal ''homelands'' in South Africa had no rights of permanent residence outside those areas, and they had few economic opportunities within them. As a result, they depended on the ecosystem resources that the areas offered, and in many cases overexploited them. In this type of relationship between poverty and the environment, particularly when property rights are not clearly defined and resource management institutions are weak, poor people can sink further into poverty as they are driven to participate in unsustainable resource use regimes. [11]

Inequities in the distribution of the costs and benefits of ecosystem change are often displaced to other places, groups, or future generations. For example, the economic clout of cities enables many urban populations to draw on resources from distant ecosystems, and this trend is expected to continue with increasing urbanization; the Gariep basin assessment, for example, showed that the population of the urban area of Gauteng province in South Africa consumes nearly 30 times more wheat than is produced in the province itself. The increase in international trade is also generating additional pressures on ecosystem services around the world, illustrated in the cases of the mining industries in Chile (see Box SG4) and Papua New Guinea. In some cases, the costs of transforming ecosystems are simply deferred to future generations. An example reported widely across sub-global assessments in different parts of the world

BOX SG4

Mining, Water, and Human Well-being in Chile

San Pedro de Atacama, Chile, is located within the driest desert in the world. Surface water is limited. The present major concern is over groundwater usage and the extent to which its exploitation is sustainable. The economic activities in this area include mining, agriculture, and tourism, all of which depend on the quantity and quality of available water. The Salar de Atacama (a salty wetland) holds over 40% of world lithium reserves; mining provides 12% of employment in the municipality; and two-thirds of the regional GDP. Mining is the most important user of groundwater (almost 100% of groundwater rights). Tourism is the second largest source of employment and income, and needs fresh water for its facilities (potable water amounts to 16% of surface water rights). Local communities rely on water for subsistence agriculture and livestock raising (accounting for 83% of surface water rights). Most subsistence farmers do not have enough resources to buy water rights, when bidding against other users. Hence the shortage of water generates major conflicts over access and ownership rights among the competing users.

was tropical deforestation, which caters to current needs but leads to a reduced capacity to supply services in the future.

The condition and trends of many ecosystem services, observed at multiple scales, are declining in many locations worldwide.

The sub-global assessments showed that ecosystem services are declining in many regions around the world. Despite some gains in the provisioning of food, water, and wood, the ecological capacity of the systems to continue to provide services is at risk in several locations. Problems with provisioning services include deterioration of water quality, deterioration of agricultural soils, and insufficient supply to meet demand. Some of the threats affecting regulating services are loss of forest cover, rangeland degradation by overgrazing (particularly in drylands), loss of wetlands to urban development and agriculture, and change in fire frequency. Problems with cultural services include loss of cultural identity and negative impacts from tourism. Biodiversity is decreasing due to the loss and fragmentation of natural habitats and the reduction of species population sizes, particularly of large bodied species, species occupying high trophic levels, and species that are harvested by humans. [8]

Conclusions on conditions and trends may differ between global and sub-global analyses. Although there was overall congruence in the results from global and sub-global assessments for services like water and biodiversity, there were instances where local assessments showed the condition as either better or worse than expected from the global assessment. For example, the condition of water resources, as assessed in the sub-global assessments, was significantly worse than might have been expected from the global assessment in places like São Paulo (Brazil) and the Laguna Lake Basin (Philippines). (See Figure SG3.) On the other hand, biodiversity condition in the Gorongosa-Marromeu component of the southern Africa assessment (SAfMA) was assessed to be better than the global assessment suggested. There were more instances of results differing between the global and sub-global analyses for biodiversity than for water provisioning, because the concepts and measures of biodiversity were more diverse in the sub-global assessments. [8]

The biophysical drivers of change mentioned most often across the sub-global assessments were land use change, climate change and variability, pollution, and invasive species. These drivers were seen, at best, as only partially under the control of the decision-maker at the particular scale of analysis. Land use change comprises a whole range of processes, including urbanization and urban growth (for example, São Paolo or Portugal), encroachment on natural ecosystems by agriculture (for example, Eastern Himalayas or Coastal British Columbia), and infrastructure development (for example, Tropical Forest Margins or the Caribbean Sea). A striking example of invasive species is in the Caribbean Sea, where dust blown from the Sahara across the Atlantic introduced new pathogenic bacteria that were at least partially responsible for coral reef diseases in the last two decades. [7]

Economic growth, structural change, and globalization were the most commonly identified indirect drivers. Their impacts on ecosystems are mediated by institutional and sociopolitical factors. Evidence from the sub-global assessments suggests that the impact of these indirect drivers depends on a range of institutional settings and on the structure of growth itself. The economic changes of the 1990s introduced a market system in the Altai-Sayan ecoregion in Russia and Mongolia. This resulted in higher cashmere producer prices, which in turn encouraged intensification of herding and the movement of herd locations closer to marketplaces, thus inducing overstocking in surrounding areas. On the other hand, in Trinidad, the liberalization of trade and the resulting competition forced down local prices of produce, which made local production of market crops uneconomical. The increase in transport triggered by global trade is seen as a major indirect driver for increases in species invasions. For example, the release of ballast water by ships coming from the Indo-Pacific region resulted in the introduction of the green mussel *Perna veridis* to Trinidad in the early 1990s. The mussel clogs up the intake pipes of industrial facilities in Trinidad, costing millions of dollars annually to remove. In a period of ten years, the mussel spread across the Caribbean all the way to Tampa Bay, Florida. However the mussel is also being harvested as a source of food in some parts of the Caribbean. [7]

Interactions among the drivers of ecosystem change in the sub-global assessments were seen to be of three major types: processes that trigger, reinforce, or constrain one another. The introduction of EU policies in Portugal *triggered* a high degree of dependency on decisions made at the European level, which in some cases may not be appropriate for local decision-making on ecosystems and their services. The Tropical Forest Margins assessment revealed that the resettlement projects designed to relieve pressures on the natural and social environment in the densely populated regions of coastal Southeast Asia have

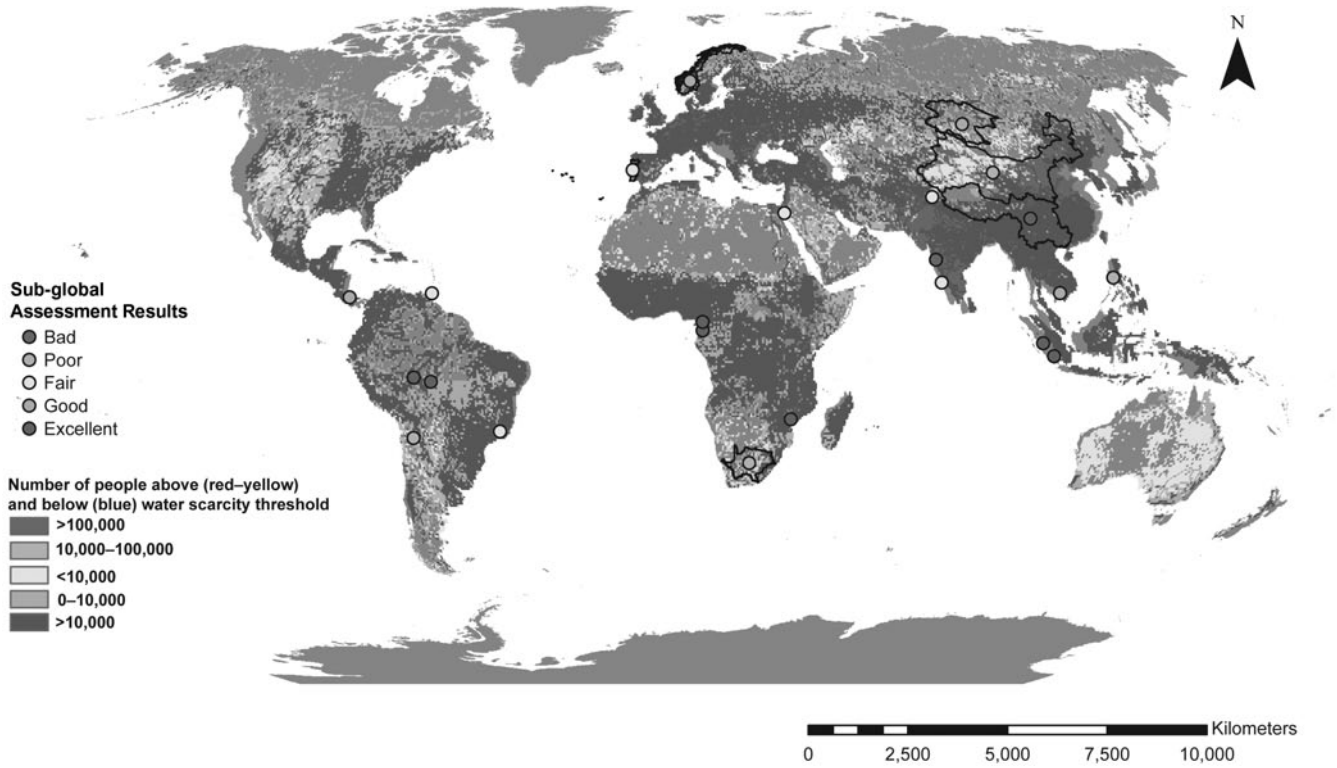

Figure SG3. Comparison between Freshwater Condition in the Sub-global Assessments and the Global Distribution of Human Population in 1995 Relative to a Threshold of Severe Water Scarcity. This map shows the distribution of the human population which faces severe water limitations (i.e., which is above the water scarcity threshold). The threshold corresponds to a ratio of 40% of water use or withdrawal to discharge (Vörösmarty et al. 2000). Boundaries of sub-global assessments that assess large areas are plotted in black.

reinforced processes of land use change, with swidden agriculture being the main driver in the processes of deforestation in the tropical forest margins. Cases where one driver is *constrained* by the action of another serve as a starting point for appropriate interventions. In the Stockholm Urban assessment in Sweden, for example, institutional change is a potentially effective intervention because it can constrain urban sprawl, a major driver of loss of green areas. [7]

Drivers of change act in very distinct ways in different regions. Though similar drivers were present in different assessments, their interactions, and thus the processes leading to ecosystem change, differed significantly from assessment to assessment. Though the three regions of the Amazon, Central Africa, and Southeast Asia in the Tropical Forest Margins assessment have the same set of individual drivers of deforestation, the processes of change in each region are distinct. Deforestation driven by swidden agriculture is more widespread in upland and foothill zones of Southeast Asia than in other regions. Road construction by the state followed by colonizing migrant settlers, who in turn practice slash-and-burn agriculture, is most frequent in lowland areas of Latin America, especially in the Amazon Basin. Pasture creation for cattle ranching is causing deforestation almost exclusively in the humid lowland regions of mainland South America. The spontaneous expansion of smallholder agriculture and fuelwood extraction for domestic uses are important causes of deforestation in Africa. While human-controlled drivers play a major role in determining the condition of ecosystem services, local biophysical constraints such as climate and soils also limit the production of ecosystem services. [7]

Drivers operate over different spatial and temporal scales, and the spatial and temporal scales of any given driver may be related in different ways. For a large number of drivers identified in the different sub-global assessments, drivers operating over large spatial areas tended to be associated with slower processes of change, while ''small'' processes tended to take place relatively rapidly. However, a significant number of exceptions to this pattern were observed. For example, the São Paulo assessment mentioned governance and legislation as a local, but slow driver. The same held for soil degradation as a biophysical driver in Viet Nam. On the other hand, in San Pedro de Atacama, Chile, the rapid change of technology in the mining sector taking place globally appeared as an important driver. This characteristic of technology—that is, fast change at the global, or at least national, scale—also held for the Argentine Pampas. [7]

Identifying effective response options that enhance human well-being and conserve ecosystem services requires consideration of drivers at different scales and involvement of actors at the appropriate scales.

Understanding drivers, their interactions, and the consequences for ecosystem services and human

well-being is crucial to the design of effective responses. Although many responses target specific problems with ecosystem services, the nature of ecosystems means that such responses can have unintended consequences for multiple interacting drivers. Individual drivers may be difficult to influence without affecting others, and therefore response options targeted at interactions among drivers are often a more effective way to achieve a desired outcome, and may enable a more integrated and holistic approach to ecosystem service management. The adaptive co-management approach adopted by the Kristianstad Wetlands assessment in Sweden is an example; adaptive co-management systems are flexible, community-based systems of resource management tailored to specific places and situations, supported by, and working with, various organizations at different levels. Similarly, the river rehabilitation councils in the Laguna Lake Basin of the Philippines addressed a number of social and ecological drivers and engaged various stakeholders at different scales, resulting in several effective responses. [7, 9]

Scenario-building is an important method for involving stakeholders in policy formulation and for encouraging citizens to adopt their own policies aimed at environmental protection. The relevance, significance, and influence of the scenarios that are constructed will ultimately depend on who is involved in their development. Decision-makers may have difficulty introducing new policies designed to alter behaviors without the support of the general population. Participants in scenario-building can provide essential input on the relevance of storylines being developed and on the nature of uncertainties that are important at sub-global scales. [10]

Sub-global assessments used scenarios for multiple purposes, which often extended beyond the rationale for global scenarios. Besides being used by all of the sub-global assessments as a tool for decision-makers to plan for the future (as in the global scenarios), most sub-global assessments, such as SAfMA and the Northern Highlands Lake District of Wisconsin, also used scenarios as a means of communicating possible future changes and major uncertainties to stakeholders. In the San Pedro de Atacama, Chile, and the Bajo Chirripó, Costa Rica, assessments, for example, scenarios also proved to be an important tool for acquiring data about stakeholder preferences, perceptions, and values. In a few cases, including the Wisconsin, Caribbean Sea, and SAfMA assessments, scenarios had a role in defining the boundaries within which discussions about management and policy options relevant to ecosystem services and human well-being could be held. All of these examples also illustrate the use of participatory scenario development approaches in the sub-global assessments. [10]

Scenarios in the sub-global assessments differed markedly from the scenarios developed at the global level, although all were based on the same conceptual framework. The most significant differences were in terms of key uncertainties (which were much more context-specific at the local level), stakeholders involved, and the scales of analysis. Almost all sub-global scenarios identified institutional arrangements/governance as the key uncertainty, even with widely varying ecological and socioeconomic circumstances across the sub-global assessments. Many sub-global assessments sought to quantify the scenario storylines, but time constraints and the lack of available models prevented many from doing so, with the exception of the Western China and SAfMA Regional assessments. (See Figure SG4.) Nonetheless, substantive links were maintained with the global scenarios in the SAfMA, Caribbean Sea, and Portugal assessments, for example, through the use of global models in the development of regional scenarios. [10]

The effectiveness of a response is related to the degree of coherence among different types of policies and the degree of collaboration among stakeholders. Horizontal (multisector) collaboration ensures that multiple objectives (ecological, social, cultural, economic) are addressed in an integrated fashion. Vertical (multilevel) collaboration facilitates the generation of resources and increases the likelihood that responses have a positive impact on direct and indirect drivers of ecosystem change. Since these drivers typically occur at a continuum of social and ecological scales, responses would need to involve decision-makers (and actors) at multiple organizational levels. For instance, local responses such as coping and adapting to environmental change by the Bedouins in Egypt and by local communities in southern Africa have been largely ineffective due to the lack of institutional and financial support at the national level. In contrast, local people in the Eastern Himalayas took the initiative to form eco-development committees, and this became an effective response thanks to facilitative support from legislators. Collaboration is not only a local phenomenon; it has been initiated by all categories of actors operating at all identified organizational levels. [9]

Collaboration among actors is often facilitated by ''bridging organizations.'' These provide arenas for multisector and/or multilevel collaboration for conceiving visions, trust-building, collaboration, learning, value formation, conflict resolution and other institutional innovations. Bridging organizations lower the transaction costs of collaboration and of crafting effective responses. They provide social incentives to identify possible win-win responses. The facilitation, leadership, and social incentives provided by bridging organizations or key persons in the community appear to be essential for capacity-building. For instance, in Kristianstad Wetlands, Sweden, a new organization called Ecomuseum has initiated a process based on collaboration, trust-building, and conflict resolution. Through voluntary participation within the existing legal framework, the ecosystem approach has been applied and an area with declining ecosystem services is now being transformed into a UNESCO Biosphere Reserve. In the Laguna Lake Basin of the Philippines, public agencies and nongovernmental organizations formed river rehabilitation councils that have been able to address social and ecological drivers in a collaborative and effective way. In San Pedro de Atacama, Chile, the assessment team provided the arena for collaborative learning, trust-building, visioning, and conflict resolution. These three examples illustrate the formation of bridging

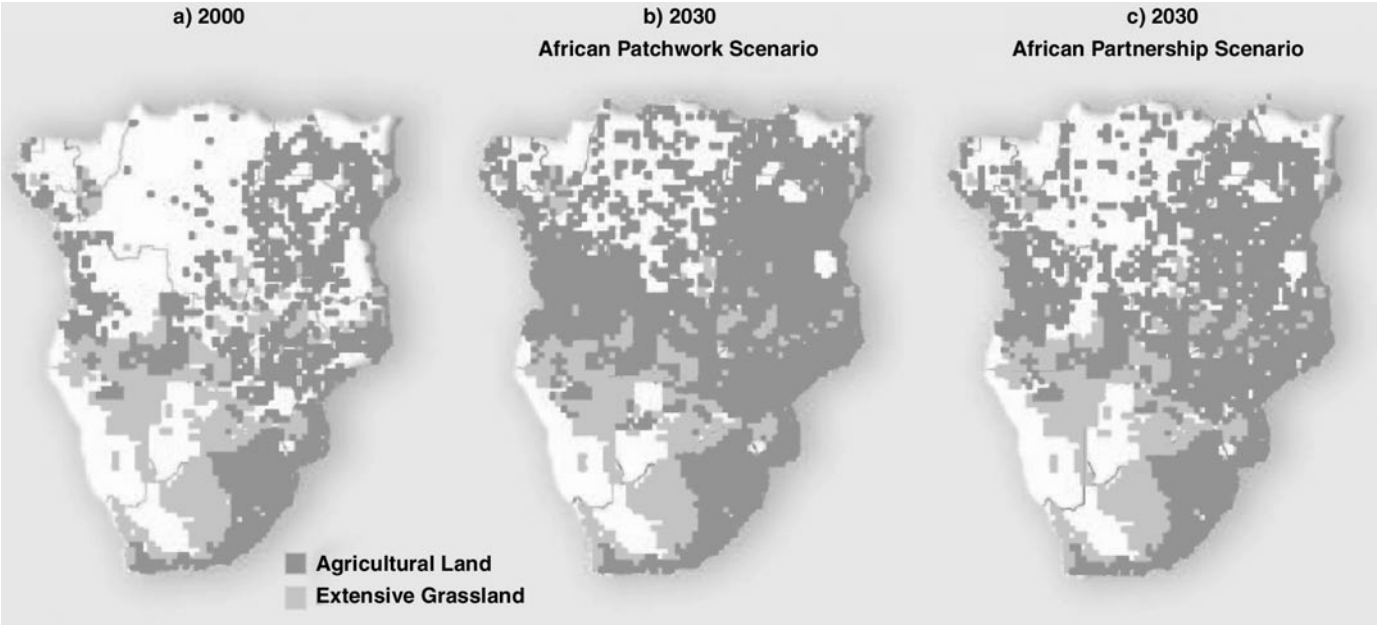

Figure SG4. Scenarios for Land Use Change in Southern Africa, 2000–2030. Under the Patchwork Scenario (low economic growth scenario), a greater area is converted to agriculture than under the Partnership Scenario (high economic growth). In both cases, the major changes occur north of the Zambezi river and are mainly due to increased livestock numbers rather than increased crop area. The model assumes that livestock are grazed extensively in the grassland areas and intensively on a portion of the area otherwise used for agriculture.

organizations that have resulted from bottom-up, top-down, and external initiatives, respectively. [9]

Declining ecosystem trends have been mitigated by innovative local responses. The "threats" observed at an aggregated, global level may be overestimated or underestimated from a sub-global perspective. Assessments at an aggregated level may fail to take into account the adaptive capacity of sub-global actors. Through collaboration in social networks, actors can develop new institutions and reorganize to mitigate declining conditions. On the other hand, in crafting their responses, sub-global actors tend to neglect drivers that are beyond their immediate influence. Hence, it is crucial for decision-makers to develop institutions at the global, regional, and national levels that strengthen the adaptive capacity of actors at the sub-national and local levels to develop context-specific responses that do address the full range of relevant drivers. The Biodiversity Management Committees in India are a good example of a national institution that enables local actors to respond to biodiversity loss. This means neither centralization nor decentralization but institutions at multiple levels that enhance the adaptive capacity and effectiveness of sub-national and local responses. [9]

When people with different interests, experiences, and knowledge cooperate, the potential diversity and effectiveness of response options is enhanced. Besides the democratic appeal of public participation, the knowledge base is broadened when local, traditional, and indigenous knowledge systems are acknowledged. By close monitoring of a diverse set of ecological variables, local stewards are often able to observe and understand early signals of ecosystem change, and distinguish this from natural variability. This is illustrated by Kristianstad Wetlands, Sweden, where local steward organizations observed declining bird populations and other signals that sparked the formation of a bridging organization. [9]

Local communities are not mere spectators, but active managers of the capacity of ecosystems to deliver services.

Ecosystems provide a sense of place and identity for local people, in addition to other ecosystem services. These intangible values, including aesthetic and recreational values, provide a rationale for management and precipitate management practices that enhance ecosystem resilience through caretaking and custodianship. In Vilcanota, Peru, spiritual values and belief systems, including the belief in Pacha Mama (Mother Earth) that encompasses the view that Earth is a living being, have allowed for the maintenance of a cultural identity among the Quechua peoples of the southern Peruvian Andes. In the Kristianstad Wetlands, Sweden, local farmers have once again begun to cultivate land previously abandoned, not primarily for economic gain, but more for the sense of place and identity that comes with the cultivation of this land. However, in many instances these values and belief systems have been eroded, leading to a shift in community-based management practices. For example, in San Pedro de Atacama, Chile, the erosion of the collective indigenous identity due to economic development has led to the sale of land to outsiders, and a consequent decline in agriculture and related traditional practices. [11]

Diversity in ecosystems and their services is important in reducing communities' vulnerability. Most

communities seek to maintain a diversity of livelihood options. This diversity buffers people against shocks and surprises such as climatic and economic fluctuations. In Papua New Guinea and India, for example, local farmers cultivate a wide variety of crops to avert the risk of crop failure. In Costa Rica, local communities create a mosaic landscape, consisting of sacred places, springs, agroecosystems, and high mountains. This results in a diversity of livelihood options at the local level. [11]

Local management systems are continuously evolving; some disappear while others are revived or newly invented. Many communities possess local, indigenous, or traditional knowledge about the interactions between humans and ecosystems. Local communities can affect ecosystem services and human well-being both positively and negatively. For example, in Xinjiang, western China, local people have elaborate traditional underground water harvesting structures (''karez'') that maintain both water quality and quantity. Traditional community institutions that regulate access to the karez water exist, but in some cases are being weakened. In the Eastern Himalayas, India, economic incentives for private forest owners have led in some instances to deforestation in native forests. Nevertheless, the recognition of the role of communities as stewards of ecosystem services, and their empowerment, is essential to strengthen local capacity to manage ecosystems sustainably for human well-being. [11]

Communities are affected by larger-scale processes, but their ability to cope with and shape change varies. Decisions taken at higher scales often do not take into account the realities of local communities, resulting in negative impacts at the local level. Communities that cope successfully with these external forces have learned to adapt or even take advantage of them by creating horizontal links with other groups, forming alliances with powerful actors at ''higher'' spatial scales, and linking with national or global processes such as policy forums, markets, and multinational agreements. The Vilcanota assessment in Peru is driven by the indigenous communities there to meet their own needs, and the link to the global MA process has provided benefits to both these communities and the wider MA process. When conditions become impossible to adapt to, for example due to inflexible national policies, people are forced to migrate or face a reduced quality of life. In Sistelo, Portugal, for example, a government afforestation program on common property land (*baldio*) diminished the locally available livelihood and coping strategies by reducing land available for pastoralism, thereby accelerating the process of rural-urban migration. [11]

3. Why Conduct an Integrated Assessment at Multiple Scales?

The scale at which an assessment is undertaken significantly influences the problem definition and assessment results, as well as the solutions and responses selected.

A *comprehensive* multiscale assessment incorporates at least two nested-levels of complete, interacting assessments, each with a distinct user group, problem definition, and expert group. While the overall MA process was a multiscale assessment as defined here, the sub-global assessments ranged from comprehensive multiscale assessments to single scale assessments with explicit multi-scale linkages or considerations. Only two sub-global assessments were conducted as *comprehensive* multiscale assessments with separate assessments at different scales (Southern Africa and Portugal). Other assessments, such as the Argentine Pampas, Coastal British Columbia, Colombia, and Western China, included significant *multiscale analyses* (for example, detailed case studies of particular sub-regions within the overall assessment) but were not *comprehensive* multiscale assessments since the case studies did not include their own user groups and problem definitions. All of the MA sub-global assessments examined processes that occur at multiple scales. [4]

The scale at which an assessment is undertaken significantly influences the problem definition and the assessment results. Findings of assessments conducted at different scales will differ due to differences in the questions posed and/or the information analyzed. Local communities are influenced by global, regional, and local factors. *Global* factors include commodity prices—for example, global trade asymmetries that influence local production patterns, as in Colombia (see Box SG5), Portugal, SAfMA Gariep, and Altai-Sayan—and global climate change. Examples of the latter include sea level rise (Papua New Guinea) and receding glaciers (Vilcanota, Peru, and Altai-Sayan). *Regional* factors include water supply regimes (for example, safe piped water in rural areas, as in SAfMA Gariep), regional climate (desertification as in Portugal), and geomorphological processes (soil erosion and degradation, as in Altai-Sayan and Trinidad). *Local* factors include market access (for example, distance to market, as in Papua New Guinea), disease prevalence (malaria, as in India Local and Papua New Guinea), or localized climate variability (patchy thunderstorms, as in SAfMA Gariep). Assessments conducted at different scales tend to focus on drivers and impacts most relevant at each scale, yielding different but

BOX SG5

Coffee and Forests in Colombia

The coffee-growing region of Colombia encompasses an area of more than 3.6 million hectares in the Andes, of which 870,000 hectares are currently devoted to coffee plantations. Coffee is grown in 605 municipalities in the country (56% of the national total), and involves 420,000 households and more than half a million agricultural productive units or farms. The old coffee plantations using varieties that were grown under shade trees were replaced with higher yield varieties that grow in open areas, leading to the loss of tree cover. The expansion of coffee production in other parts of the world (for example, Viet Nam) contributed to a reduction in international prices, resulting in a shift in agricultural production and changes in landscape use in the coffee-growing region of Colombia.

complementary findings. These provide some of the benefit of a multiscale assessment process, since each component assessment provides a different perspective on the issues addressed. [4]

A full multiscale assessment provides a powerful basis for evaluating the robustness and persistence of findings across scales. If an assessment of surface water availability finds that a specific region consistently experiences water scarcity across all the scales of analysis, the finding can be viewed with some degree of confidence. In contrast, if the same region is identified at one scale as water scarce, but is subsequently seen at another scale of analysis to exhibit varying degrees of scarcity and abundance, assessment teams are compelled to explore the possible reasons for such discrepancies. Inconsistency in findings across scales may stem from data or model inaccuracies or from local perceptions, needs, and/or requirements (for example, livelihood strategies at the local level that nullify broad-based patterns of access to subterranean water sources in areas that possess limited surface water). This full range of patterns emerged for different geographic areas in southern Africa analyzed by the regional, basin, and local scale assessments. [4]

Multiscale assessments offer insights and results that would otherwise be missed. The variability among sub-global assessments in problem definition, objectives, scale criteria, and systems of explanation increased at finer scales of assessment (for example, the visibility of social equity issues increased from coarser to finer scales of assessment). The role of biodiversity as a risk avoidance mechanism for local communities is frequently hidden until local assessments are conducted (examples include India Local; Sinai, Egypt; SAfMA Livelihoods). Processes of common concern emerging at all scales of assessment assumed different meanings and implications at different scales. For example, institutional responses at the global scale include formal global agreements and financial commitments, but at finer and finer sub-global scales, they increasingly involve relatively informal but effective efforts such as cooperative local resource management; examples include Caribbean Sea; India Local; Coastal British Columbia; Kristianstad Wetlands, Sweden. [4]

Using different knowledge systems provides insights that might otherwise be missed.

Local and traditional ecological knowledge added significant insight about locally important resources and management practices, revealing information and understanding that is not reflected in the global assessment. This included names and uses of locally important plant species and practices to protect them (examples include India Local and Sinai), local drivers of change, specialized soil and water conservation practices, and coping strategies to protect human well-being. Local resource users also contributed valuable long-term perspectives about their social-ecological systems (Bajo Chirripó, Costa Rica), as well as information on key ecosystem processes that are important, uncertain, and difficult to control (Wisconsin). [5]

Practitioner knowledge—the diverse knowledge of multiple stakeholders—contributed more in terms of clarifying information needs and expectations, and less in terms of ecosystem management knowledge. Few assessments had significant analysis of the contribution of practitioner knowledge to the assessment. However, the Kristianstad Wetlands (Sweden) assessment was structured so that practitioner knowledge was fully integrated within the assessment process. The Tropical Forest Margins assessment showed that, in the areas studied, practitioner knowledge has become more integrated over time as there have been intensive efforts to ensure stakeholder participation. Several other assessments encountered problems in utilizing practitioner knowledge, in many cases because practitioners were viewed as users of the assessment results instead of knowledge holders in their own right. Engagement of assessment users and other practitioners as knowledge holders requires more attention to how knowledge is used in policy-making, decision-making, and NGO and bureaucratic practice. [5]

The extent to which local and traditional ecological knowledge contributed to the assessments varied, due to local circumstances, the predisposition and expertise of the assessment team, and the resources allocated to understanding and using local knowledge. Local and traditional knowledge is both complex and inherently contextual, and a rigorous and comprehensive investigation and interpretation of such knowledge is needed to fully understand it and the insights it provides on ecosystem dynamics. Collaborative relationships, such as those developed in Vilcanota and Bajo Chirripó, as well as participatory tools that broaden the level of inquiry, often result in the emergence of key issues of local importance. For example, in the Bajo Chirripó assessment, local participants found that there was existing traditional knowledge about natural resource management strategies, so the assessment emphasized learning more about and reviving these instead of introducing new ones. [5]

The MA assumed that participation would empower local resource users in two ways. First, it would increase local ownership over the assessment process and results. Second, validation by scientists would cause decision-makers to recognize and use local knowledge. However, as local participation varied from fully collaborative to extractive, so too did the potential for empowerment. At one end of the spectrum was the Vilcanota assessment, in which local resource users designed and directed the assessment process with relatively less involvement and direction from scientists. Western China was at the opposite end: what local knowledge was used was inserted into a scientific framework where local and traditional knowledge was not central. [5]

The sharing of knowledge across scales in the sub-global assessments did not occur to the extent hoped for by the MA. This was partially due to methodological issues, such as uneven emphasis on different knowledge systems and difficulties with the validation of different forms

of knowledge. Procedures for the validation of local and traditional knowledge at the local level were adequately handled with the guidelines developed by the MA, but the sub-global assessments often lacked adequate processes of validation for the use of local knowledge at higher levels. Mediating institutions or boundary organizations are usually necessary for this, and these were not present for a number of the sub-global assessments. [5]

There is evidence that including multiple knowledge systems increases the relevance, credibility, and legitimacy of the assessment results for some users. For example, in Bajo Chirripó in Costa Rica, the involvement of non-scientists added legitimacy and relevance to assessment results for a number of potential assessment users at the local level. However, in many of the sub-global assessments, local resource users were only one among many groups of decision-makers, so the question of legitimacy needs to be taken together with that of empowerment. [5]

Some sub-global assessments confirmed that local institutions have a role in conferring greater power to local knowledge holders in cross-scale decision-making. For example, in India local and Kristianstad Wetlands (Sweden), deliberate efforts were made to embed the assessment within existing institutions that link local knowledge to higher-level decision-making processes. However, in the SAfMA Livelihoods assessment, local community institutions help to maintain knowledge, but by themselves were unable to ensure the use of local knowledge at higher-levels of decision-making. The Vilcanota and Bajo Chirripó assessments attempted to create space to begin a dialogue between local communities and decision-makers at higher scales. The success of these efforts can only be evaluated with more time. [5]

4. What Are the Important Lessons for Future Sub-global Assessments?

The MA conceptual framework served as a valuable tool and initial point of reference, but had to be adapted by some sub-global assessments.

Capturing the complex and dynamic nature of the interactions between ecosystems and humans required complementary conceptual frameworks in some contexts. Several community-based assessments adapted the MA framework to allow for more dynamic interplays between variables, capture fine-grained patterns and processes in complex systems, and leave room for a more spiritual worldview. In Peru and Costa Rica, for example, other conceptual frameworks were used that incorporated both the MA principles and local cosmologies. (See Figure SG5.) In southern Africa, various frameworks were used in parallel to offset the shortcomings of the MA framework for community assessments. These modifications and adaptations of the framework are an important outcome of the MA. [5, 11]

Capacity-building activities need to be an integral component of any assessment, but especially in a complex one such as the MA. Many sub-global assessments did not have the expertise to assess the various components of the MA conceptual framework, and there was a need to develop expertise through capacity-building activities. This included a need to develop methods to assess even the central tenet of the conceptual framework: the link between ecosystem services and human well-being. In addition to capacity-building activities initiated within assessments, the number and diversity of the assessments participating in the MA provided an ideal opportunity for capacity-building across the sub-global network. Networks formed among assessments became a way of exchanging experiences and methods and helped in the progress of some assessments. To fully incorporate multiple scales and knowledge systems in the design of all the sub-global assessments would have required more time and funding to develop the necessary tools and expertise. [6]

Multiscale assessments provide significant benefits, but they pose process and analytical challenges, are resource- and time-intensive, and, depending on assessment goals, may not always be necessary.

Both multiscale assessments and assessments incorporating multiscale analyses face analytical challenges not present in single-scale assessments. These challenges include: 1) the selection and measurement of ecosystem services and components of human well-being, and whether these should be consistent across scales; 2) determining the degree of nestedness; 3) establishing methods for cross-scale comparisons; and 4) ensuring information flow across the scales of the assessment. [4]

Multiscale assessments face additional challenges related to the most appropriate model for stakeholder involvement and participation. The presence of stakeholder groups from different scales, each with their own needs from the assessment and differing perceptions, can result in tension. Whereas a more rigid methodology and protocol may better meet analytical needs for multiscale analyses, a more flexible approach is often necessary to accommodate or adapt to different stakeholders from different scales. Thus design approaches for multiscale assessments vary depending on the requirements of analytical rigor and stakeholder involvement. [4]

Multiscale assessments are both resource- and time-intensive. These added costs may be justified when the goal is to inform and influence decisions, but a full multiscale assessment may not be necessary or desirable if the primary goal is only to formalize knowledge or to test the robustness of scientific findings. Sub-global assessments that were multiscale did obtain information benefits (improved assessment findings) related to the availability of more and better data, ground-truthing of data, and better analysis of the causes of change. However, many of these benefits could be as readily obtained (at lower cost) by

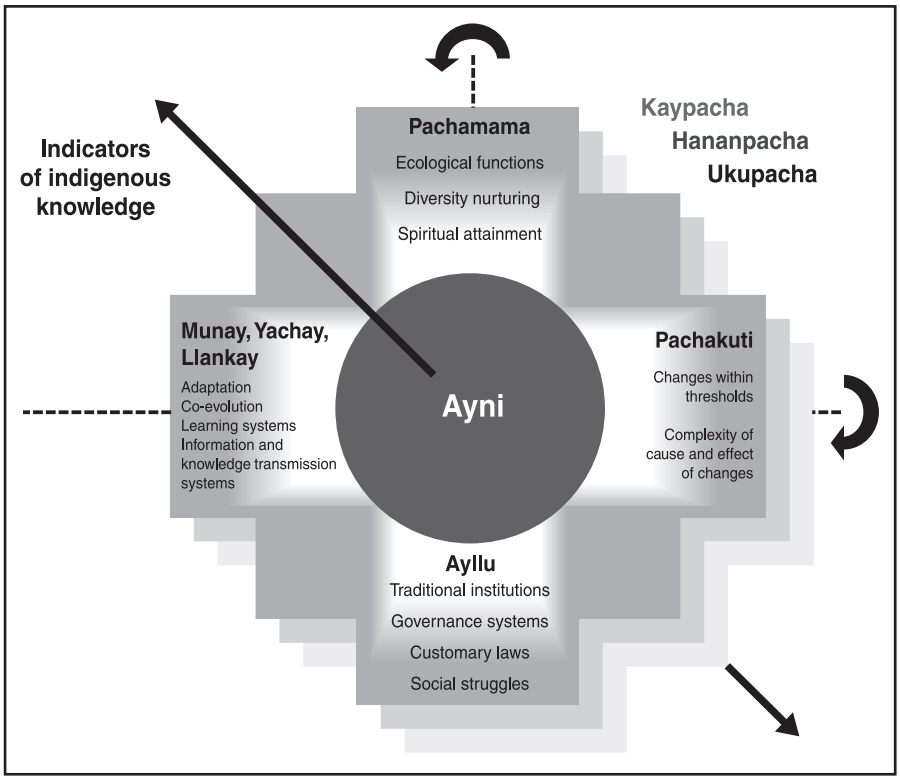

Figure SG5. Adapting the MA Conceptual Framework for Local Needs. The conceptual framework of the sub-global assessment in Vilcanota, Peru, was derived in part from the Inca cosmovision and in part from the MA conceptual framework, which was reinterpreted by the Quechua communities. The resulting framework has many similarities with the MA conceptual framework. The divergent features are considered to be highly important by the Quechua people conducting the assessment. Concepts such as reciprocity (*Ayni*), the inseparability of space and time, and the cyclical nature of all processes (*Pachakuti*) are important components of the Inca view of ecosystems. Love (*Munay*) and working (*Llankay*) bring humans to a higher state of knowledge *(Yachay)* about their surroundings, and are therefore key concepts linking Quechua communities to the natural world. *Ayllu* represents the governing institutions that regulate interactions among all living beings. *Kaypacha, Hananpacha,* and *Ukupacha* represent spatial scales and the cyclical relationship between the past, present, and future. Inherent in this concept of space and time is the adaptive capacity of the Quechua people, who welcome change and have become resilient to it. The Southern Cross shape of the Vilcanota conceptual framework diagram represents the *Chakana,* the most recognized and sacred shape to Quechua people. Chakana orders the world through deliberative and collective decision-making that emphasizes reciprocity (*Ayni*). *Pachamama* (the "mother earth," divinity, and place where past, present, and future coincide) is similar to the MA concept of ecosystem services combined with human well-being. Pachakuti is similar to the MA drivers (both direct and indirect). Ayllu (and Munay, Yachay, and Llankay) may be seen as responses, and are more organically integrated into the cyclic process of change and adaptation.

working fully at one or two scales while considering intermediate scales (multiscale analyses), rather than by conducting a full multiscale assessment. In contrast, a full multiscale design provided impact benefits associated with the use and adoption of the findings that could not be achieved through other approaches. The multiscale approach also increased the potential capacity of institutions and individuals involved to respond to changes in ecosystem services, even across existing political, national, and cultural boundaries (as in the case of SAfMA). [4]

For success, a sub-global assessment requires understanding of the context, adequate resources, champions and actively engaged users, and a governance structure able to manage competing needs.

The sub-global assessment process was dynamic and iterative. An assessment that links science with policy, such as the MA, provides a critical, objective evaluation and analysis of information, to meet user needs and support decision-making on complex issues. The three main stages of the assessment process were: an exploration stage, a design stage, and implementation of the resulting work plan, which included the review, validation, and communication of the findings. Throughout these stages, ongoing communication and user engagement permitted a flexible and iterative process, with some overlap between stages. (See Figure SG6.) [6]

Each sub-global assessment process was embedded in political, social, and environmental circumstances. The heterogeneity of these circumstances, as well as constraints such as the availability of information or particular expertise, necessitated a variety of approaches to using the MA conceptual framework. This reflects the reality of conducting integrated assessments at the sub-global level. An exploration of institutions that could potentially

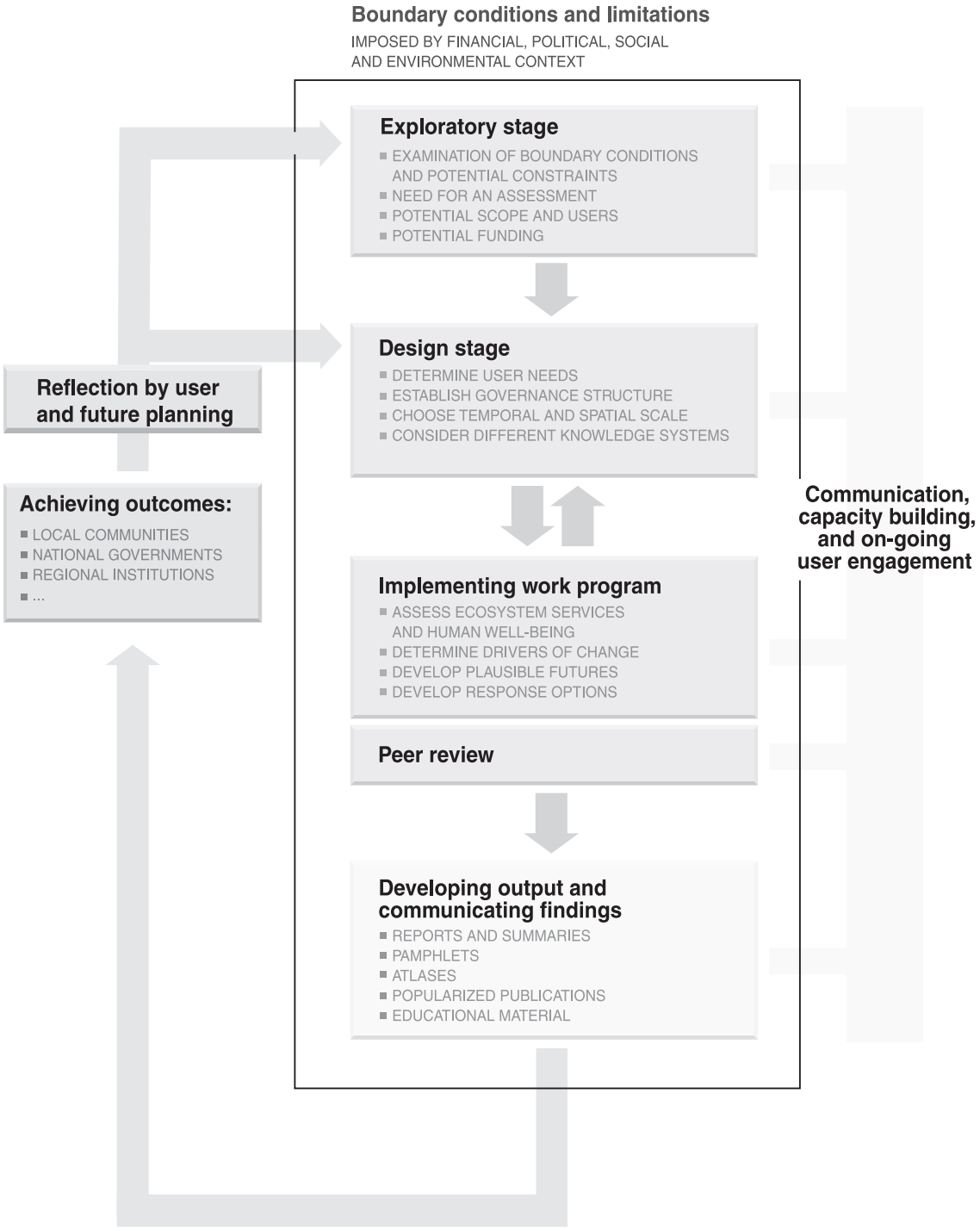

Figure SG6. The Sub-global Assessment Process

implement assessment outcomes should be included in the exploratory stages of the assessment. [6]

The sub-global assessments faced multiple constraints and had to overcome these challenges in order to make progress. Constraints included lack of data, limitations in financial support, and limited time. Further challenges included gaining the trust of different users, establishing and maintaining user engagement, securing technical leadership, and building the capacity to conduct multiscale, integrated assessments. These constraints limited the scope of the sub-global assessments in terms of the number of ecosystem services and aspects of human well-being that were included, the temporal and spatial scales considered, and the knowledge systems incorporated. Sub-global assessments that incorporated different knowledge systems required more time and resources to be set aside to support innovative work on these aspects. [6]

Assessments need champions. In many cases, specific individuals played key roles that were critical for providing the needed momentum and direction during different stages of an assessment. These roles include that of external facilitators who helped to establish the demand for an assessment,

and leadership to guide and sustain the assessment process. In some cases, small dedicated teams of people championed the assessment together. [6]

The groups that will use the assessment results must be involved throughout the entire assessment process, from the design of the assessment through to the communication of findings. Working with assessment users to identify processes that would use the assessment findings was essential, as it was an important part of establishing the demand for an assessment. The sub-global assessments responded to three broad categories of need for an assessment: (1) summary and synthesis of information on complex issues to support decision-making; (2) strengthening the capacity of the users to assess and manage their resources or to participate in resource management; (3) research to address gaps in knowledge for resource management. For the first two categories in particular, the assessments involved strong user engagement throughout the process. [6]

A governance structure that provided a forum for discussion was necessary in assessments that involved a wide range of users. Many sub-global assessments considered diverse user needs and needed to manage the tensions between them, as well as allocation of resources for competing needs. This included prioritizing the components of the MA conceptual framework to be addressed. [6]

The sub-global assessment process has generated new tools and methodologies and baseline information that have helped to empower stakeholders; more products and outcomes will come to fruition in the future.

The sub-global assessments have yielded a number of tangible outcomes. Most global assessments, including the global component of the MA, have focused on producing synthetic reports, with their findings as the main outcome. In this regard, the final reports from individual sub-global assessments (or, for those assessments still in progress at the time this volume was written, peer-reviewed 30-page summaries) are a comparable result. Each of these assessments contains a wealth of information regarding the condition of ecosystem services, scenarios, and response options, each focused and shaped by the circumstances and needs of their particular setting. In addition, this volume aims to provide an overview of the sub-global process, with some comparisons and emerging patterns observed to date.

The sub-global assessment process has catalyzed the development of new tools and methodologies, the collation and generation of baseline information, and the creation of governance mechanisms that empower stakeholders. The constraints faced by the sub-global assessments sometimes led to innovative approaches to overcoming these constraints. Examples include the development of a novel biodiversity intactness index by the Southern Africa Regional assessment, and the training of technicians and video operators in the Peruvian Andes to lead and document the assessment of soil, water and agrobiodiversity by community groups. Another example was the advisory group of the San Pedro de Atacama assessment in Chile—which brought together different stakeholder groups to discuss ecosystem management for human well-being, for the first time. [12]

Some important results from the sub-global assessments are less tangible, and are primarily related to capacity-building. These include the capacities that were developed to lead and undertake similar, and improved, assessments in the future. These capacities will be reinforced by the network of institutions and professionals that has been developed in the course of the MA. One example was the development of a fellowship program for younger scientists, many of whom went on to work closely with the Coordinating Lead Authors of this assessment volume.

The value added by sub-global assessment processes in the future can be increased. In doing so, the following tradeoffs should be taken into consideration:

- a rigorous approach to selecting assessments will ensure better geographical coverage and representation of ecosystems, but this should be weighed against the benefits of more innovation, diversity and strong user demand that arise from a bottom-up selection process;
- fully nested, multiscale assessments will deliver significant information and impact benefits, but may not always be necessary, especially in the light of the substantial resources and capacity required to undertake them; and
- focusing on a small set of services in common across all sub-global assessments will facilitate greater comparability, but the diverse circumstances and priorities of individual assessments may necessitate flexibility and a less rigidly uniform analytical approach.

A number of important additional considerations for future sub-global assessments would include:

- ensuring the availability of essential training and capacity-building, and tools and methodologies, especially in areas like developing scenarios and multiscale approaches to assessment;
- fostering continued interdisciplinary approaches involving both natural and social scientists, to comprehensively analyze the links between ecosystem services and human well-being; and
- sufficient funding for the full set of assessment activities planned.

Some of the most important results of the sub-global assessment process are yet to come. The existing sub-global assessments are at very different stages of implementation, ranging from completed assessment to those in their early stages. It is important to build on the experience gained so far and to continue the existing network. This will also enable a better assessment of the real impact of the process on the management of ecosystems for human well-being. [12]