Chapter 4

The Multiscale Approach

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Main Messages

The MA sub-global assessments were undertaken to meet the information needs of decision-makers at every scale, as well as to test methods for conducting multiscale assessments on ecosystem services and human well-being. This work was conducted in the face of acknowledged and recognized limits in our understanding of multiscale assessment approaches.

A *comprehensive* multiscale assessment is a process that incorporates at least two complete, nested, and 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, four categories of sub-global assessments emerged: *comprehensive multiscale assessments; multiscale assessments via analyses; single-scale assessments with explicit multiscale linkages;* and *single-scale assessments with either significant multiscale linkages or with multiscale considerations.* Only two sub-global assessments were conducted as comprehensive multiscale assessments (SAfMA and Portugal). Four other assessments (Argentine Pampas, Coastal BC, 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.

The scale at which an assessment is undertaken significantly influences the problem definition and the assessment results. Findings of assessments conducted at different scales differed due to differences in the questions posed and/or the information analyzed. Local communities are influenced by global, regional, and local factors. Assessments conducted at different scales tended to focus on drivers and impacts most relevant at each scale, yielding different but complementary findings. These differences are the basis for some of the benefits of a multiscale assessment process, since each component assessment offers a different perspective on the issues addressed.

Both multiscale assessments and assessments incorporating multiscale analyses face analytical challenges not present in single-scale assessments. Assessments that include analyses undertaken at different scales must grapple with analytical issues not faced in assessments undertaken at single scales, including: (1) the selection and measurement of ecosystem services and components of human well-being, (2) determination of the degree of nestedness; (3) establishment of methods for aggregating or downscaling in order to allow a comparison across scales, and (4) establishment of mechanisms for ensuring information flow across the scales of the assessment.

Multiscale assessments face additional challenges related to the most appropriate model for stakeholder involvement and participation. "Tensions" may emerge from conflicting perceptions created by the presence of separate stakeholder groups from different scales, each with their own needs from the assessment. Whereas a more rigid methodology and protocol may better meet analytical needs for multiscale analyses, a more flexible approach is sometimes necessary to accommodate or adapt to stakeholders from different scales. Thus the two goals of analytical rigor and stakeholder involvement frequently lead to somewhat incompatible multiscale assessment design approaches that must be reconciled.

Policies and institutions designed to enhance the sustainability of the management of ecosystem services at any particular scale often result in winners and losers at finer scales and this, in turn, can lead to the emergence of new institutions and actions at those scales. National policy decisions about market conditions, trade, or transportation typically create winners and losers at local scales. Such tensions can precipitate coalitions and socio-political arrangements among people at more localized levels that aim to overcome skewed power relationships (Coastal BC). These emergent responses and institutions must be accommodated in the design of approaches to manage ecosystem services and to enhance human well-being. Multiscale assessments can be particularly helpful not only by revealing these emergent institutions, but also by highlighting their potential role in managing ecosystem services for human well-being (Caribbean Sea; Sweden KW).

***Comprehensive* multiscale assessments provide a powerful basis for evaluating the robustness and persistence of findings across scales.** An assessment of surface water availability that consistently identifies water scarcity across all scales of analysis means that confidence in the result can be high. In contrast, if a region is identified as water scarce at one scale, but is found to exhibit varying degrees of scarcity and/or abundance at others, assessment teams are compelled to explore the reasons for such discrepancies. Inconsistent findings across scales may stem from data or model inaccuracies, or from local adaptations (for example livelihood strategies at local levels that nullify surface water shortages, such as access to subterranean water sources). All of the above outcomes emerged at different localities in one assessment (SAfMA).

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 comprehensive multiscale design may not be required if the primary goal is only to formalize knowledge or to test the persistence of patterns. Both the information benefits (that is, how the approach improves the assessment findings) and the impact benefits (that is, how the approach improves the adoption and use of the findings) from the assessments were explored. *Comprehensive* multiscale assessments do provide information benefits: more and better data, ground-truthing of data, and better analysis of the causes of change. Many of these benefits can also be obtained at lower cost by using fewer scales and analyzing intermediate scales (*multiscale analyses*). Comprehensive multiscale designs provide benefits associated with the use and adoption of findings through increased stakeholder ownership and subsequently their capacity to implement and respond to assessment findings (SAfMA).

Multiscale assessments offer insights and results that would otherwise be missed. The variability among sub-global assessments in problem definitions, 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 (India Local; Sinai, SAfMA Livelihoods). Processes of common concern emerging at all scales of assessment assumed different meanings and implications at different scales. Examples include *market forces* (which at global scales govern broad allocations of resources such as increases or decreases of forest cover, but at local scales determine livelihood strategies, security, organizational, technical, employment and migration responses); *environmental degradation* (which at global scales involves phenomena like climate change and biodiversity loss, but at local scales becomes increasingly tied to a suite of tradeoffs associated with the provision of ecosystem services upon which livelihoods depend); and *institutional responses* (which range from global agreements and financial commitments to cooperative local resource management and advocacy-aimed capacity-building efforts).

4.1 Introduction

The MA was a multiscale assessment, that is, it consisted of component assessments undertaken at multiple spatial scales, ranging from individual villages to the globe. Attempts were made to inform the findings at each scale with the findings from assessment components undertaken at other scales. The MA sub-global assessments were carried out not only to meet the needs of decision-makers, but also as a means of testing methods for conducting multiscale assessments related to ecosystem services and human well-being. This work was conducted in the face of acknowledged and recognized limits in our understanding about using multiscale approaches (Wilbanks and Kates 1999; Giampietro 2003; Rotmans and Rothman 2003).

Recognition of the importance of scale in the context of environmental assessments has grown considerably over the past decade (Wilbanks 2003). However, there has been relatively little experience with the use of a multiscale assessment structure in international scientific assessments. Most recent international scientific assessments have been conducted at a single, global scale, such as the Global Biodiversity Assessment, the World Water Development Report, and the Ozone Assessments. Regionalization of the findings from a global assessment perspective was done in the Intergovernmental Panel on Climate Change Third Assessment Report (IPCC 2001). The Global International Waters Assessment, in contrast, is based on nearly 60 sub-global assessments, but again it is not a multiscale assessment since it is based on assessments conducted at a single scale. UNEP's *Global Environment Outlook* process (UNEP 2002) is a global assessment based largely on regional assessments, although it comes somewhat closer to a multiscale structure in that it complements the regional assessments with a global analysis.

This chapter presents the rationale for adopting a multiscale assessment approach, assesses the strengths and weaknesses of the process and methods employed to conduct a multiscale assessment, and evaluates the effectiveness of the approach. Specifically, it examines the extent to which the benefits expected from a multiscale approach were in fact achieved.

4.2 Rationale for a Multiscale Assessment

4.2.1 Definitions

Scale refers to the measurable dimensions of phenomena or observations (MA 2003). It is expressed in physical units, such as meters or years, population size, or quantities moved or exchanged. In observation, scale determines the relative fineness and coarseness of different details, and the selectivity among the patterns that these data may form. Thus scale becomes a filter, or a window of perception through which analysis, observation, knowledge, and information can be considered and/or defined. The details and patterns identified in the assessment of a farm field differ from those apparent in assessing the river basin containing that field. In explanation and action, scale expresses the reach of processes of interest, or the bounds used to confine such processes for analytical or social reasons. For example, a metropolitan region may extend to incorporate its market links, it may be scaled analytically to explain housing patterns, or it may be divided variously among rural and urban jurisdictions for purposes of governance and plans of action.

Hierarchies of scales are viewed primarily as emergent and/or regulating structures, processes, and interactions across a range of spatial and temporal scales (Allen and Starr 1982; O'Neill et al. 1986; Holling 1992; Levin 1992; Berkes 2002; Gunderson and Holling 2002). For example changes to the observable characteristics of cities, towns, and villages are influenced by interactions at coarser scales: the processes of urban resource extraction from rural areas and of rural-to-urban migration. Similarly, a reduction of a species' access to its food supply, whether by natural or human-induced events at a coarser scale, may produce adaptive responses throughout the trophic system of which both predator and prey are part, modifying the extent of influence and characterizing processes of all groupings within the system.

The terms "scale" and "level" are often confused because both are defined within hierarchical frameworks and can coincide in the same unit. Their meanings are different, however. Scale is a measure of extent, span, size, reach, or detail; it is physically measurable. Level is a characterization of perceived influence; not a physical measure, it is what people accept it to be. A network of cooperating irrigation farmers can contain dozens or thousands of farmers, operating at different scales but on the same level, while state-run irrigation systems at both scales of dozens or thousands of farmers may be perceived to be operating at a "higher" level. Species at "lower" trophic levels may occupy larger areas for longer times than their predators, which are defined as "higher" as a matter of convention. While the two concepts of scale and level may coincide in the same unit (for example, a village), the scale of the village as a unit of land and population is a physical measure. Its level may be "high" or "low" depending upon, for example, the relative power, wealth, and networks of its occupants, or whether its ecological site is perceived to control or respond to events in the broader landscape. A level of organization is not a scale, but it can have a scale (Allen 1998; O'Neill and King 1998).

The concept of scale can be either applied to the scale of observation of a process or considered a characteristic of the process. (See Box 4.1.) An example of the use of the concept to describe the scale of observation would involve one assessment measuring or observing changes in river hydrology at the scale of a particular catchment area, while another assessment examines changes at the scale of an entire river basin. Many ecological and social processes or phenomena, however, are characterized by a particular extent or duration over which the process or phenomena is expressed; this is referred to as the "characteristic scale." Addressing these characteristic scale phenomena at any other scale can often result in an incomplete (sometimes even mistaken) representation. (See Box 4.2.) For example, cyclical seasonal changes have a characteristic annual time scale that can be misconstrued if viewed only over the span of a few months.

Cross-scale interactions refer to situations where events or phenomena at one scale influence phenomena at another

BOX 4.1

The Evolving Definition of Scale in the MA Sub-global Assessments

Scale was a fundamental MA concept (MA 2003), but the execution of the MA sub-global assessments revealed it to be a far richer and more complex concept than had been anticipated in the initial design. Although initially framed in terms that would achieve consistency between global and sub-global assessments, scale emerged in practice as a dynamic concept that differed, at any one place and moment, depending on whether it was being applied to a problem definition, to an empirical observation, to analysis, or to anticipated action. Moreover, each of these changed in response to the varied contexts of the sub-global assessments as well as the learning that occurred within the assessment teams themselves. What began as a sharply-defined static expectation of scale, emerged as a demonstration of real-world dynamics and ranges of variability. In turn, the sub-global assessments shed light on how even the apparently unambiguous definition of a global scale embraced more possibilities of interpretation than had originally been construed.

scale. The process of forest harvesting, for example, takes place at local scales but can in turn influence regional weather (through changes in evapotranspiration) and global climate (through changes in carbon sequestration). Cross-scale interactions are features of both ecological and socio-economic systems. For example, regional trade agreements that change commodity prices have impacts on local scale decisions regarding what crops a farmer will plant in a particular year.

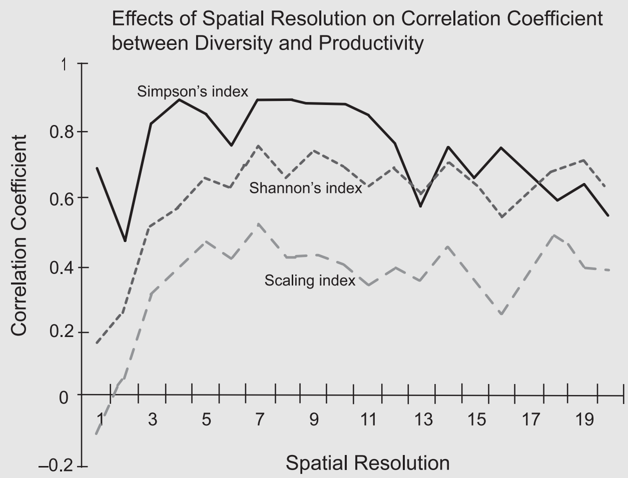
The MA defined an assessment to be a social process that brings the findings of science to bear on the needs of decision-makers. An assessment thus involves close interaction between the experts carrying out the technical work of the assessment and the intended users of the findings of the assessment. The users—that is, the individuals who will act on the findings of the assessment—help to frame the issues that will be assessed. The experts mobilize, synthesize, and assess the data and information bearing on the issues identified by the users (Giampietro 2003). While the overall MA process was a multiscale assessment as defined here, this chapter distinguishes four categories of multiscale assessments among the MA sub-global assessments: *comprehensive multiscale assessments, multiscale assessments via analysis, single-scale assessments with explicit multiscale linkages,* and *single-scale assessments with multiscale considerations*. (See Figure 4.1.)

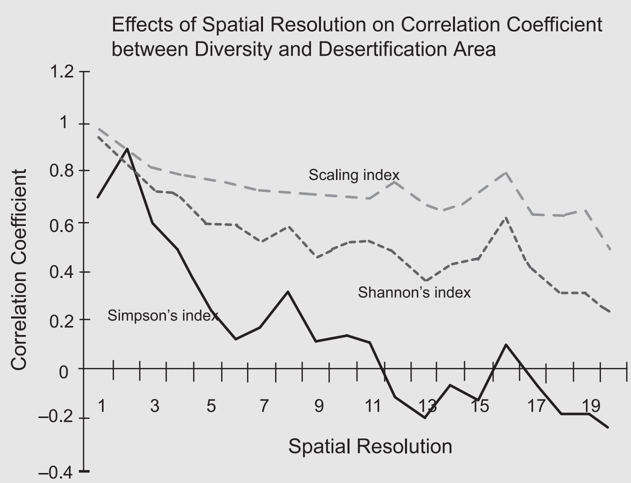
We define a *comprehensive* multiscale assessment process to be one that consists of at least two complete, interacting assessments, one nested within the other, each with its own group of experts, users, and problem definition. Thus the MA global assessment had a set of users involving five international conventions and was undertaken through three global working groups. Nested within the global assessment was, for example, the Southern African Millennium Ecosystem Assessment, which itself consisted of three distinct scales of assessment. At the broadest scale was the SAfMA Regional assessment, which has its own advisory group of users, its own group of experts carrying out the assessment,

BOX 4.2

The Problem of Scale in an Assessment: Western China

The relationship between biodiversity and ecosystem functions such as stability and productivity has a long history of debate. In the Western China sub-global assessment, these relationships were tested in order to highlight their scale dependency (Yue et al. 2004). Results indicate that analyzing the relationship between the ecosystem services provided by biodiversity and its proxy variables is not only complex from the perspective of understanding key processes, but can also present methodological challenges. As the figure below illustrates, unraveling the relationship between these two variables is a difficult task, which is made even more challenging by the fact that the relationship changes with respect to the index chosen to encapsulate biodiversity (there are a large array of biodiversity indices, each of which yields different conclusions when relating these measures to productivity; see CBD 2003 and Magurran 2004), as well as the spatial scale of analysis. From a policy perspective, the figure indicates how focusing on a single observational scale to measure geographically continuous phenomena can lead to incomplete or sometimes simply mistaken conclusions on the nature of ecosystem services.





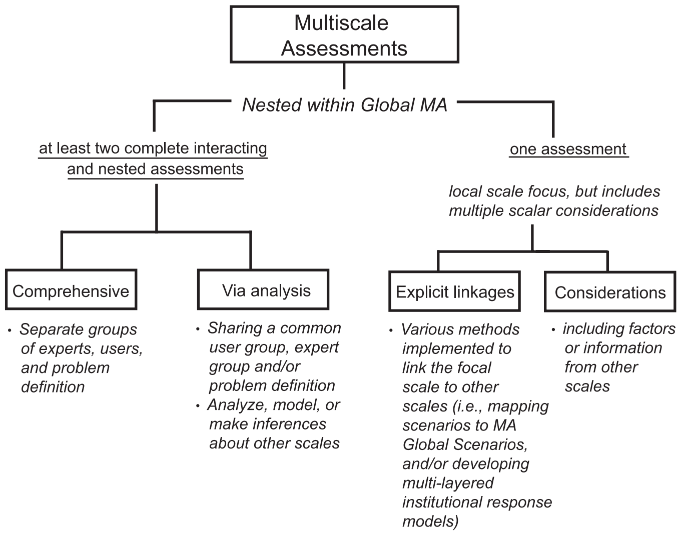


Figure 4.1. Characterization of the Multiscale Nature of the Sub-global Assessments

and its own reports and products addressing the needs of users from the region of southern Africa. Nested within the regional-scale assessment were the Gariep and Zambezi basin assessments. Nested in turn within SAfMA Gariep were, for example, the Richtersveld and Great Fish River local assessments, which again had their own user groups (local communities), experts (including many community members), and products.

There are two different ways in which an assessment could be construed as a *multiscale assessment via analysis:* by adapting information from other scales or by modeling of intermediate scales. For example, the IPCC is a global assessment carried out for a global body of users as represented by the parties to the U.N. Framework Convention on Climate Change. The IPCC increasingly uses multiscale analyses as a component of its work, incorporating regional analyses of the costs and benefits of climate change and regional analyses of the drivers of climate change such as carbon emissions. We would therefore describe the IPCC assessment as one that incorporates *multiscale analyses,* but not as a *comprehensive* multiscale assessment. While the IPCC reflects on and incorporates inputs from other scales, it does not conduct assessments at different scales. MA sub-global assessments in the multiscale analysis category include: Coastal BC, Western China, Tropical Forest Margins, Argentine Pampas, and Colombia.

A single-scale assessment in the context of the MA is defined as having one complete assessment at a single scale with either *explicit multiscale linkages* or with *multiscale considerations. Explicit multiscale linkages* can take the form of mapping the global MA scenarios to local scenarios (see Chapter 11) or of developing multi-layered institutional response models (Sweden KW, Sweden SU, Northern Range, Caribbean Sea, and Tropical Forest Margins). A single-scale assessment with *multiscale considerations* takes into account drivers, stakeholders, processes, or patterns from other scales within the context of the focal scale of analysis (Altai-Sayan, San Pedro de Atacama, India Local, PNG, Laguna Lake Basin, Vilcanota, Downstream Mekong, Bajo Chirripó, Eastern Himalayas, Sinai, and São Paulo).

4.2.2 Expected Benefits of a Multiscale Assessment Process

The idea of conducting the MA as a multiscale assessment was introduced at the first exploratory steering committee meeting for the MA in 1998. This was then refined through a series of meetings during the design phase of the MA, shaped by the growing literature on this topic (Clark 1985; Holling and Meffe 1996; Wilbanks and Kates 1999; Kremen et al. 2000; Kates and Wilbanks 2003; Holling et al. 2002; Giampietro 2003; Rotmans and Rothman 2003).

Considerations of temporal and spatial scales are highly relevant for assessments of processes of social and ecological change (MA 2003). Ecosystem changes may affect human well-being over days or weeks (for example, pest outbreaks that reduce agricultural yields), years, decades (for example, increased sediment loads leading to eutrophication and declining productivity of coastal estuaries), or even longer time frames (for example, global climate dynamics). Similarly, changes at a local (that is, fine) scale may have little impact on some ecosystem services at that scale (as in the local impact of logging a forest patch on water availability) but have major impacts at coarse scales (forest loss in a river basin changing the timing and magnitude of downstream flooding regimes). These points are especially important in cases where ecosystems are shared among different countries, where the transboundary externalization of environmental problems may be frequent.

Scale considerations are important for the MA with respect to the causes and impacts of ecosystem change. For example, factors affecting ecosystems include drivers with global impacts such as climate change and invasive species introductions, regional impacts such as regional trade or agricultural policies, and local impacts such as land use practices and the construction of irrigation systems. In addition, changes to ecosystems can have global consequences such as the contribution of deforestation to climate change; regional consequences such as the impact of nutrient loading in agricultural ecosystems on coastal fisheries production; and local consequences, such as the impact of overharvesting or land degradation on local food security.

Scale considerations are also important in the assessment of response options. Policy, institutional, technological, and behavioral responses to ecosystem-related issues can involve global actions such as international financial support for biodiversity conservation (Global Environmental Facility and Conservation International); regional action such as regional agreements to promote wetlands conservation for migratory bird protection; and local responses, such as a decision by a farmer to alter land management practices to conserve topsoil. Indeed, unlike some global environmental issues such as climate change, a large share of the decisions affecting ecosystems take place at sub-global, including local, scales. The decisions that will ultimately matter most will be those taken by national governments, private companies, individual land owners, and local land managers.

By the time the technical work of the MA global and sub-global assessments began in 2001, the rationale for the multiscale structure of the MA involved two basic expectations. First, it was expected that the use of a multiscale structure would provide *information benefits* by improving the assessment findings, and their applicability, at all scales. Second, it was expected that the use of a multiscale structure would also provide *impact benefits* for the assessment, by improving the relevance, utility, ownership and legitimacy of the assessment with decision-makers.

4.2.2.1 Information Benefits

The information benefits that would be expected from a multiscale assessment (in contrast to a single-scale assessment) would arise for the following reasons:

- *Better problem definition* (Kates and Wilbanks 2003). A single-scale assessment tends to focus too narrowly on the issues, theories, and information most relevant to that scale. Perspectives gained from other scales would contribute to a fuller understanding of the issues.
- *Improved analysis of scale-dependent processes.* As noted, many ecological and social processes exhibit a characteristic scale. If a process is observed at a scale significantly smaller or larger than its characteristic scale, there would be a likelihood of drawing the wrong conclusions (MA 2003). For example, a short-term observation of a trend in temperature or precipitation (over a week or month) cannot be used to infer long-term changes in climate. Similarly, global aggregate information tends to mask the basic patterns of ''winners and losers'' that often are responsible for the ecosystem changes occurring at the local level and that largely define the potential response options available to communities. (See Chapter 11.) Figure 4.2 illustrates how the net gains from climate change, and the winners and losers therefrom, vary by spatial scale.
- *Improved analysis of cross-scale effects.* Understanding cross-scale effects is often key to understanding processes of ecological and social change. For example, the direct cause of a change in an ecosystem is often intrinsically localized (a farmer cutting a patch of forest), while the indirect drivers of that change (for example, a subsidy to farmers for forest clearing) may operate at a regional or national scale. Similarly, some ecosystem services are *delivered* at finer scales but *produced* through processes operating at coarser scales. For example, food is produced at a local, short-term scale, but this production is also governed by regional processes such as climate and watershed dynamics (for example, availability or quality) and by long-term processes such as soil formation (for example, turnover of organic material) and maintenance (for example, cropping practices).
- *Better understanding of causality.* The relationships among environmental, social, and economic processes are often too complex to fully understand when viewed at any single scale. Studies at additional scales are often needed to fully understand the implications of changes at any given scale. For example, a farmer's choice of which crop to plant in any given period is not only determined by local climate and soil characteristics, but also strongly influenced by the prevailing market prices for specific crops, which are a function of other scales of organization. At the same time, market prices are themselves a function of aggregate demand and supply.

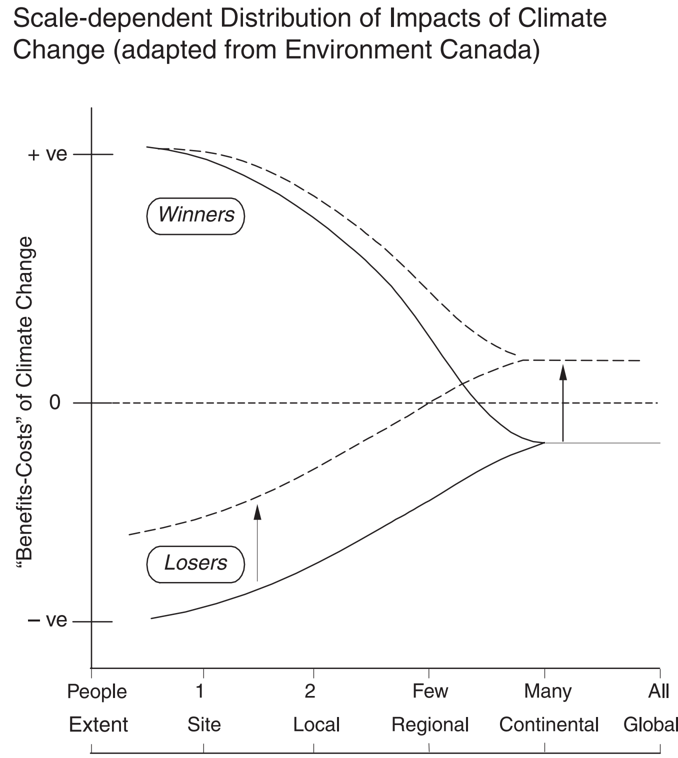


Figure 4.2. Effects of Geographic/Economic Scale on Net Gain, Benefits minus Costs, Arising from Effects of Climate Change on Society and Adaptation's Possible Role in Mitigating Negative Outcomes (Wilbanks 2003)

- *Improved accuracy and reliability of findings.* Sub-global assessment activities can help to ground-truth the global findings. Aggregated global syntheses necessarily leave out local details. However, when those aggregated conclusions or indicators clearly diverge from the on-the-ground reality at a specific locality, they can be very misleading. This situation can arise when the problem has been inadequately defined, or when ''best available'' data used for global syntheses is in fact not sufficiently reliable to enable local interpretation.

4.2.2.2 Impact Benefits

The information benefits would presumably also enhance the ultimate use and impact of an assessment, since the assessment findings would be more credible and reliable. However, multiscale assessments were also expected to provide other benefits in addition to those related specifically to the scientific findings; these additional benefits were expected to be obtained from multiscale assessments by virtue of the presence of separate user groups in a *comprehensive* assessment process conducted at different scales. Specifically, the impact of each component assessment was expected to be enhanced through the multiscale structure for the following reasons:

- *Improved relevance of the problem definition and assessment findings for users and decision-makers.* The primary purpose of each MA sub-global assessment was to meet the needs of the decision-makers or users at the location and scale where each component assessment was undertaken. Differences in the framing of the issues to be addressed in an assessment can provide benefits in terms of the analysis (as noted above), but can also make an assessment far more relevant to users at different scales. Clearly, an assessment focused on (and dictated by) the specific needs of the users at that scale will be more relevant than an assessment in which users have little input.
- *Improved scenarios.* An important element of the MA process was to develop and explore scenarios to help reveal the impact of changes in ecosystem services on people. The key uncertainties that a local community may identify as differentiating reasonable future pathways of development may often be different from those identified by users at regional or global scales. At each scale, the scenarios used could thus incorporate the effects and considerations from coarser and finer scales.
- *Increased ownership by the intended users.* Even if an assessment is technically credible and focused on relevant issues, the intended users of an assessment may not use the findings if they do not feel a level of ownership in the process or if they do not view it as politically legitimate (Clark and Dickson 1999). A multiscale structure could increase the legitimacy of each of the component assessments. For example, the legitimacy of the global assessment could be enhanced for governments by virtue of the presence of sub-global assessments in individual countries. In particular, any country undertaking one of the sub-global assessments would likely have greater ownership in the global findings. Similarly, the legitimacy of sub-global assessments for the users of those assessments could be enhanced by virtue of its participation in a globally authorized assessment mechanism.
- *More balanced assessment results.* The choice of scale for an assessment is not politically neutral, because that selection may intentionally or unintentionally privilege certain groups (MA 2003). The adoption of a particular scale of assessment limits the types of problems that can be addressed, the modes of explanation, and the generalizations that are likely to be used in analysis. For example, users of a global assessment of ecosystem services would be interested in some issues such as carbon sequestration that may be of relatively little interest to users of a local assessment. In contrast, the users of a local assessment might be more interested in questions related to sanitation or local commodity prices that would not necessarily be the focus of a global assessment. Similarly, a global assessment is likely to implicitly devalue local knowledge (and the interests and concerns of the holders of that knowledge) since it is not in a form that can be readily aggregated to provide useful global information, while a local assessment would reinforce the importance of local knowledge and the perspectives of holders of that knowledge. Incorporating multiple assessments in a single process balances the various approaches and helps mitigate potential structural biases associated with the choice of scales.
- *Increased capacity-building.* The MA was created with the dual goals of meeting decision-makers' needs and building institutional and individual capacity to undertake integrated assessments and act on their findings. While there would be opportunities to meet this capacity-building goal at the global scale, for example through the involvement of new experts in the global assessment process, the opportunities were expected to be much greater at sub-global scales, where more individuals could receive training in the assessment approach and more institutions could become involved in the process.

The MA experiment with a multiscale approach is ongoing, since many MA sub-global assessments were not yet completed as this volume was written. Even so, the experience gained thus far provides important lessons regarding the process of designing and carrying out a multiscale assessment. There is already sufficient evidence available to allow a preliminary assessment of which expected benefits were actually achieved, and at what costs.

4.3 MA Design and Process

4.3.1 Multiscale Characteristics of the Sub-global Assessments

The original MA design called for a relatively top-down approach to the establishment of four clusters of sub-global, multiscale assessments, three of which were to be located in developing countries/regions and one in an industrial country/region. Each of these multiscale clusters was to involve at least two nested assessments from the following broadly defined categories: one regional assessment, one or more national (or basin-level) assessments, and one or more local assessments. These clusters of assessments were to be complemented by one "outlier assessment" (to address important ecosystems not included in the four clusters) and one "cross-cutting assessment" to examine similar ecosystems at similar scales in different regions.

Only one such cluster, the Southern African Millennium Ecosystem Assessment, was actually established following this top-down approach to developing nested clusters of assessments. This approach proved to be cumbersome, and by early 2002, the MA Sub-Global Working Group proposed a bottom-up approach for establishing other sub-global assessments. (See Chapter 6 for a detailed discussion.) Using this approach, small seed grants were provided to facilitate the establishment of further sub-global assessments.

Under both the top-down and bottom-up approaches, the choice of scales for a particular assessment was determined by the proponents of each assessment. Through both selection criteria and funding criteria, however, the MA did attempt to encourage the establishment of multiscale assessments. Specifically, the MA selection criteria for sub-global assessments stated that nesting was to be one of two key features of MA sub-global assessments ("*a goal of the selection process will be that most of the assessments included in the MA will involve at least three scales of 'nesting'—e.g., a local assess-*

ment nested within a regional assessment nested within the global assessment''). The criteria also indicated that assessments with more than two scales of nesting would be given higher priority for funding. The MA selection criteria further stated that ''*all MA sub-global assessments must actively engage with assessments undertaken at larger (i.e. coarse) and smaller (i.e. fine) scales*'' (MA 2002).

The scales of the MA sub-global assessments (or component assessments of multiscale sub-global assessments) were generally described in geographical terms (for example, the Altai-Sayan Ecoregion, the SAfMA Gorongosa-Marromeu transect, small islands of PNG) or sociopolitical terms (for example, Indian local villages and Portugal). Scale in this context refers to the perceived influence of the dominant issues or questions being addressed by each assessment. Thus the Portugal assessment focused on changes taking place in ecosystems in Portugal, and the effect that those changes have on the people of Portugal. But in order to assess the state of knowledge bearing on those questions, the Portugal assessment did not restrict its analysis to processes taking place at the scale of the country. The assessment examined global processes (for example, the potential impacts of global climate change or changes in trade regimes), regional processes (for example, policies that the European Union might establish that would affect ecosystems in Portugal), national processes (for example, changes in the fishing industry), and local processes (abandonment of agricultural fields in Sistelo, a community in northern Portugal). Similarly, each sub-global assessment examined processes across a range of time scales, selecting those most relevant to the issues being addressed.

The scale of each sub-global assessment thus described the lens that was used to focus the assessment and, in the user-driven assessment process, was heavily influenced by the questions that the users sought to have the assessment address. The scale of an assessment, however, did not restrict the processes or phenomena that were examined—most assessments examined processes at coarser and finer scales.

In general, there was a positive correlation between the geographical extent of an assessment and the time window that it addressed. (See Figure 4.3.) This pattern is consistent with the expectation that processes with relatively coarse spatial extents will also have relatively long temporal windows. However, exceptions do exist: for example, broad climate processes, such as *El Niño,* may act over relatively short time horizons (years), while relatively localized processes such as local nutrient cycles may take place over decadal time spans.

All of the MA sub-global assessments were, by definition, part of a multiscale assessment, since each was nested in the global assessment and interacted with the MA global working groups. However, the sub-global assessments themselves differed significantly in the extent to which each was conducted as a multiscale assessment. Table 4.1 summarizes the categories of scalar considerations of selected sub-global assessments. Most (14 out of 23) operated at a single spatial scale, while considering relevant factors operating at various scales or information from other scales. As all of these assessments were nested within the global assessment, each had the potential to be involved in at least a two-scale assessment process. Only two MA sub-global assessments, Portugal and SAfMA, were *comprehensive* multiscale assessments as defined above. Two other assessments, Western China and Coastal BC, included significant multiscale analysis within their processes, even though they did not completely fit the definition of a *comprehensive* multiscale assessment. Although the nesting of the sub-global assessments themselves was therefore far less than originally intended, this set of assessments still provides a significant basis for examining the benefits of a multiscale structure by virtue of the fact that each was nested within the global assessment.

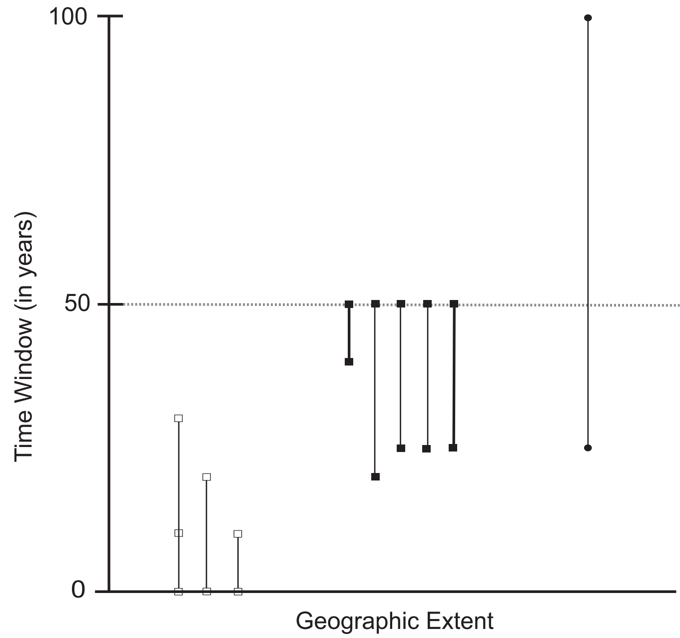


Figure 4.3. Relationship between Geographical Extent of the Sub-global Assessments Relative to the Time Window Addressed by Each. Lines represent the time window (in years) used to analyze the status of ecosystem services. Note that an increase in geographical extent (scale) of consideration appears to be positively correlated with the time window considered in the assessment. This pattern is consistent with the expectation that processes with relatively large spatial extents (which will tend to be the focus of assessments at coarser scales) will also have relatively longer temporal windows.

The assessments that incorporated *comprehensive* nested assessments (SAfMA and Portugal) or nested case studies (Argentine Pampas, Coastal BC, Western China) were structured in somewhat different ways. (See Figure 4.4.) SAfMA involved separate assessments undertaken at three scales (multi-country region, river basin, and local community), and every finer-scale assessment was nested within the next coarser-scale assessment. Western China, with two explicit scales of analysis, followed a similar fully-nested design (with each of the five smaller scale sub-regions nested within a larger regional scale assessment) but involved only two scales (regional and sub-regional). Portugal involved

Table 4.1. Scalar Aspects of Selected Sub-global Assessments. The categories presented here on the nature of multiscale considerations across the sub-global assessments are distinguished by the relative emphasis given to more than one scale of analysis. (See Figure 4.1.) An assessment is characterized as a *comprehensive multiscale assessment* if each of its component assessments has a primary goal of meeting user needs at the scale where it is conducted, has an identifiable user group (typically represented by an advisory group or board at that scale), and is producing separate products specifically addressing the needs of the user group at each scale. An assessment is considered to be an *assessment that incorporates multiple scales via analysis* if it has significant analytical components focused on different scales (for example, a set of case study sites at different scales). *Assessments at a single scale* also include factors or information from other scales.

			Assessment at a Single Scale with:			
Assessment	Comprehensive Multiscale Assessment	Assessment that Incorporates Multiple Scales via Analysis	Explicit Linkages	Multiscale Considerations	Spatial Scale	Temporal Scale
Altai-Sayan				yes (transboundary ecoregion in Altai and Sayan mountain ranges in Russia, Mongolia, Kazakhstan, and China)	local basin national ecoregion	unspecified
San Pedro de Atacama				yes (Salar de Atacama salt marsh in the northern desert of Chile)	local	20 years
Caribbean Sea			yes (regional assessment of marine and island systems in the Caribbean)		regional	25–50 years
Coastal BC		yes (northern and central coastal region of British Columbia)			site subregion region	unspecified
Tropical Forest Margins		yes (a large-scale tropical forest analysis with regional and local case studies at the basin and household levels)	yes (cross-cutting assessment of sites in the forest margins of the humid tropics in South America, Africa, and Southeast Asia)		local basin regional	25–50 years
India Local				yes (local villages in Karnataka and Maharashtra states in India	local	unspecified
Norway				yes (pilot assessment in the Glomma basin in southern Norway)	basin	unspecified
PNG				yes (coastal, small island, and coral reef systems nationwide, with a focus in Milne Bay Province)	local	10 years
Laguna Lake Basin				yes (Laguna Lake basin near Metro Manila)	local	10 years for most ecosystem services, 30 years for fisheries

Portugal	yes; national assessment with case studies at the basin level (Mondego Basin and Mira Basin) and at the local level (Sistelo, Quinta da França, Herdade de Ribeiro Abaixo, and Castro Verde)				local basin national	50 years
SAfMA	Yes; regional assessment of southern Africa (SAfMA Regional); Gariep basin (SAfMA Gariep); Zambezi basin (SAfMA Zambezi); local assessments in Gariep basin (SAfMA Livelihoods), and Gorongosa-Marromeu (SAfMA G-M)				local basin regional	25–50 years
Sweden KW				yes (local assessment: Kristianstad Wetlands)	local	unspecified
Sweden SU				yes (local assessment: Stockholm Urban)	local	unspecified
Northern Range			yes (Northern Range)		sub-national national	25 years
Vilcanota				yes (Vilcanota region of Peru)	local	unspecified
Downstream Mekong				yes (downstream Mekong wetlands)	local	unspecified
Western China		yes, entire western region of China, with six typical sites			local basin regional	20–50 years
Argentine Pampas		yes (farms scale, ecoregions, pampas region, basin)			local ecoregion basin production zone	1–40 years
Bajo Chirripó				yes (local assessment)	local	unspecified
Colombia		yes; district, department, meta-region (main coffee producing)			local sub-region region production zone	Unspecified
Eastern Himalayas				yes (local assessment)	local	unspecified
Sinai				yes (local assessment)	local	unspecified
São Paulo				yes (three reservoirs)	local	10 years

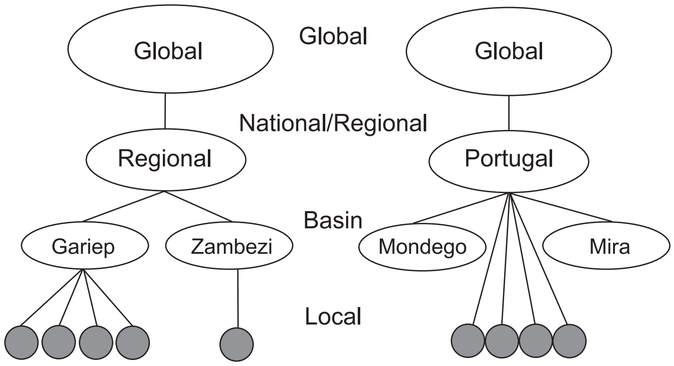


Figure 4.4. Nested, Multiscale Design of Southern Africa and Portugal Assessments. The Portuguese assessment was undertaken at three scales: national, basin, and local. There were two basin assessments and four local assessments. The local case studies were not within the basins studied, and covered different reporting units (systems) of the national assessment. These were a very small rural community (mountain system), two farms (cultivated system) and a biological research station (montado system). Within the Southern Africa assessment, five local-scale assessments, each covering the area of a community or local authority, were nested within two basin-scale assessments, which in turn lay within an assessment of the greater SADC region. All contributed to the global-scale assessment. (Adapted from Box 9.6)

three explicit scales of analysis (national, basin, and local), with nesting between the national scale and the basin scale, and between the national scale and the local scale, but not between the basin and local scales themselves. Western China is not considered a *comprehensive* multiscale assessment, as the smaller scale analyses formed case studies for the larger-scale analyses rather than full assessments in themselves. Similarly, Argentine Pampas incorporated various scales of analyses and envisaged a multiparty stakeholder approach. Importantly, these differences in the design strategies employed also reflected how the ecological and social dimensions of the various sub-global assessments were addressed.

The *comprehensive* multiscale assessment design, as utilized by Portugal and SAfMA, was by far the most resource-intensive assessment approach. This is because it required independent data sets, as well as independent groups of experts and stakeholders. SAfMA employed global data sets for the regional assessment, national statistics and data sets at the basin level, and local statistics and information derived directly from local communities for the local assessments. The comprehensive multiscale assessment designs provided significant benefits in terms of the level of stakeholder engagement and ownership of the findings at different scales, and it provided a powerful basis for evaluating the consistency of findings across multiple scales.

One consequence of the diversity in nesting designs used by the various sub-global assessments was that the assessments differed with respect to the intermediate layers of assessments between a given component assessment and the global assessment. At one end of the spectrum, the single-scale sub-global assessments had no intermediate layers between their assessment scales and the scale of the global assessment. At the other end of the spectrum, the local assessments in Portugal and the community assessments in southern Africa were linked to the national or regional assessments, with an intermediate link within southern Africa between the two at the basin level. These were, in turn, linked to the global assessment. This difference allowed exploration of the costs and benefits of the presence of these intermediate layers. For example, does the presence of multiple intermediate layers result in a heavy filtering of the information and perspectives from the local assessments such that they have less influence on the global findings? Or, alternatively, does the presence of multiple intervening layers of assessments provide a mechanism to better amplify the local findings for use in the global assessment?

The sub-global assessments also adopted different approaches to obtain some of the benefits related to the involvement of stakeholders at different scales, even when they did not use a *comprehensive* multiscale assessment structure. The Swedish assessments (Sweden KW and Sweden SU), which were local, single-scale assessments, involved stakeholders from local, regional, and national scales, and from multinational organizations, all of them representing particular constituencies and bringing additional information, insights, and needs from different scales to the assessment process. This arrangement had several advantages, in that it led to better problem identification and assisted with the analysis of scale-dependent processes and cross-scale interactions. However, the ownership of any particular group of stakeholders in the process will likely be lower, and the responsiveness of the assessment to the specific needs of stakeholders at any particular scale could also diminish as a result of this multiscale stakeholder strategy.

4.3.2 Adaptations of the MA Conceptual Framework across Scales

Although the sub-global assessments participated in the formulation of the MA conceptual framework (MA 2003), the application of the conceptual framework proved to be challenging for many sub-global assessments. (See Chapter 6.) Some of these challenges in applying the conceptual framework appeared to relate to scale. In general, the MA conceptual framework tended to be more readily applied at coarser scales than finer scales, even within individual multiscale assessments, such as the SAfMA. (See Box 4.3.) A common concern expressed by the sub-global assessments related to the difficulty of capturing the multidimensional aspects of interactions at the local scale in the MA conceptual framework. (See Chapters 6 and 11.) Many sub-global teams argued that the conceptual framework implied a relatively static and deterministic relationship among drivers, ecosystem services, and human well-being, when it was strictly applied at a local scale. These assessments (mainly, SAfMA Livelihoods, Vilcanota, and Bajo Chirripó) spent a significant portion of their time reshaping the MA conceptual framework to capture the multidimensional perspectives of the local level. (See Chapters 5 and 11.)

Capturing these multidimensional perspectives required not just considerable investments of time, but also innovative

BOX 4.3
The MA Conceptual Framework across Multiple Scales: SAfMA

During the initial planning meeting, a common design framework for SAfMA was established. The decision was to have a *regional* assessment, *basin-scale* assessments (as water was considered an important driver in the region), and *local* community assessments. The scale of the local assessments was interpreted in a loose fashion to accommodate the focal issues to be explored in those assessments. Thus some local assessments turned out to be very fine-scale (for example, Richtersveld and Great Fish River), whereas others were more expansive in area covered (Gorongosa-Marromeu and Gauteng). Each of these assessments adapted the MA conceptual framework in a variety of ways.

In the regional assessment, the conceptual framework formed the basis for the way in which different ecosystem services and response options were assessed. For each service, the impact on human well-being was examined, as well as the major factors affecting the service and possible responses that could be adopted to ensure its continued provision. The conceptual framework was also used as the basis for synthesizing existing scenarios work, and developing the two regional-scale scenarios for southern Africa.

At the local level, the MA conceptual framework was useful but insufficient to tackle the complex relationship between ecosystem services and human well-being. (See also Chapter 11.) These assessments found that local people constantly adjust their livelihood strategies to cope with long-term and short-term changes in the environment. Furthermore, key resources such as water, fuelwood, food, and livestock varied in response to rainfall and trends in demand. This led to a dynamic interplay between ecosystems and humans, which required additional conceptual frameworks to be "superimposed" on the MA framework. The first, the adaptive renewal model (Gunderson and Holling 2002) enabled the conceptualization of ecosystems and humans as complex adaptive systems that undergo cycles of collapse and reorganization. The second, the sustainable livelihoods framework (Carney 1998), was useful to conceptualize livelihood strategies as long-term responses to reduce people's vulnerability rather than as short-term reactions to change. The three frameworks were used in a complementary manner, and their combined application helped the assessment team to overcome most of the shortcomings of the MA conceptual framework.

participatory methods (including, for instance, community theater techniques) to facilitate communication between assessment teams and communities with primarily oral histories. At the regional or global scale, the MA framework was better able (and thus easily adopted) to capture the dynamics of ecosystem change and impacts on human well-being. At these coarser scales, the conceptual framework also facilitated the structuring of the assessment work (SAfMA Gariep; Bohensky et al. 2004), in particular the work conducted on scenarios at the regional-scale (SAfMA Regional; Biggs et al. 2004). While the adaptation of the conceptual framework to better meet user needs at different scales increased the utility of each assessment at the scale where it was conducted, it also increased the challenge of synthesizing information across scales in the multiscale structure.

4.3.3 Mechanisms for Linking Assessment Scales

During the design phase of a multiscale assessment, considerable attention must be given to defining the mechanism and process for integrating across the different scales of the assessment. The experiences of the global MA process and of SAfMA showed that integration was difficult to achieve if such mechanisms were not already established before the assessments commenced. The lesson learned here is that, from the outset of an assessment, the methods and approaches to be used to achieve integration need to be defined as clearly as possible.

Rather than relying on statistical methods to scale results up or down across the assessment scales, SAfMA decided to use a common set of ecosystem services as the basis for comparison across scales—food, water, and biodiversity. The assessment team also decided upfront to use a scale-invariant approach that focused on assessing the differences between supply and demand for each service. In the case of water, the common variable employed was cubic meters per person per day, assessed against the U.N.-identified thresholds for water scarcity and water stress. In the case of food, kilocalories per person were used for carbohydrates while grams of protein per person were used for assessing protein nutrition compared with the World Health Organization thresholds for adequate nutrition. For biodiversity, the common approach was the average change in the population size of all species of plants and vertebrates in the particular analytical unit considered, relative to the populations in large protected areas in the same ecosystem type. This use of a common approach significantly facilitated comparisons across component assessments and subsequent integration across scales using the principle of spatial congruence. Individual component assessments nonetheless retained significant flexibility to incorporate additional variables, drivers, and stakeholder group requirements.

As part of the same approach, SAfMA used independent datasets for each of the scales analyzed. The regional assessment made use of regional and global data sets, the basin-level assessments used only national statistics and data sets, and the local assessments used only locally derived data. The principle was to avoid using the same data at different scales, as it could potentially confound the emergence of scale-specific patterns and processes. Similarly, the use of different data from various scales in a multiscale analysis can add significantly more depth and richness than an assessment conducted at only one scale.

Other MA sub-global assessments used a number of different approaches and methods to explore issues related to spatial and temporal scale relevant to their assessments and to overcome challenges related to the multiscale design. Box 4.4 describes some of these other approaches.

The steps taken to enable integration of findings with the global assessment were quite diverse. Unlike the approach taken within the Southern Africa assessment itself, the MA Sub-global Working Group did not require that common variables (or services) be measured across all of the sub-global assessments. The concern was to allow the sub-global assessments to focus on addressing the needs of users

> BOX 4.4
> **Modeling Intermediate Scales**
>
> The Western China assessment used coarse-scale and very fine-scale information to model an intermediate scale. This can be a very cost-effective method, especially if the intermediate scale is data poor and stretches over vast areas or, as in Western China, there is simply no decision-making or data assimilation incentive for intermediate scales. This approach does, however, seem to compromise the potential benefits envisioned from the benefits of a multiscale approach, especially with regard to independent data sets.
>
> Many assessments employed innovative approaches to capture the temporal trends in ecosystem services. Western China, for example, used the archives available from weather stations to assess the temporal changes of terrestrial ecosystems. Similar methods, utilizing satellite image archives and other emergent spatial technologies, to address temporal changes in ecosystem services were employed by other sub-global assessments (Argentine Pampas, Portugal, SAfMA, as well as Western China). These approaches differ from those that generated entirely new data sets, which can be used as important baseline information for future assessment efforts (India Local).

at the scale at which each assessment was conducted, rather than to be constrained by ''global'' issues and variables imposed by the Working Group. This provided sufficient flexibility to the sub-global assessments, but also made it difficult to compare some global MA findings with the sub-global assessment findings. The following primary mechanisms were established at the outset to integrate the global and sub-global findings:

- the MA Assessment Panel (the chairs of all the Working Groups were members of the Panel and took decisions regarding substantive aspects of the overall MA);
- overlap of individuals in the global and sub-global assessments;
- posting of interim sub-global assessment information on the MA Intranet for the use of global authors; and
- the review process (involvement of global authors in reviewing sub-global assessments, and vice versa).

As the assessment drafts were being prepared, it became apparent that these types of linkages were insufficient. There was relatively little reflection of the sub-global findings in the global assessment, and vice versa. The MA then established a ''global–sub-global linkage team,'' which reviewed the draft global and sub-global materials to identify possibilities for the inclusion of more sub-global information in the global reports, and vice versa. This mechanism did enhance both global and sub-global products of the MA. Much of the challenge in linking scales related to the parallel process of undertaking the component assessments in the MA. If the sub-global assessments had been completed prior to the global assessment, for example, the findings of the sub-global assessments could have been more easily incorporated in the global process but they, in turn, would have not have benefited from the findings of the global process. When viewed as a one-off assessment, this is a particularly problematic situation. However, if an assessment like the MA is repeated in the future, then there would be ample opportunity for future global and sub-global assessments to benefit from the collective MA experience.

4.3.4 Aligning Assessment and Management Scales

Given the multiple scales over which ecological processes take place, and the multiple scales over which ecosystem management decisions are made, there can never be a single ''correct'' scale at which to conduct an assessment. In general, the problem of a mismatch between assessment scale and management scale is addressed by focusing the assessment on an appropriate scale for the particular concerns and issues identified by decision-makers. Even following this approach, the availability of information or the characteristics of the ecological and social processes may mean that information cannot be provided to the decision-makers at the scale at which it will be most relevant. Within the MA sub-global assessments, some assessments selected the most appropriate ecological units for analysis, and then subsequently matched this information to the relevant sociopolitical units as closely as possible (for example, SAfMA Gariep); others chose the most appropriate sociopolitical units with secondary consideration of ecological units (for example, Western China); and others aimed to do both, depending on the context (for example, Portugal and Coastal BC). The trade-off involved is straightforward: the first approach provided more complete and accurate, but less sociopolitically relevant information, while the latter approaches increased relevance to decision-makers but at a cost to accuracy.

Some sub-global assessments also selected user groups that were not traditional decision-making bodies. The approach most often employed was to use multistakeholder groups (which included representatives from different types of decision-making bodies, some of which may function at different scales) to align management and decision-making structures with the pre-selected ecological scales (Coastal BC, Sweden KW, and Sweden SU). The advantage of this approach is that novel decision-making structures may evolve, but the downside is that ownership of issues is either not clearly defined or not readily assumed among the diverse stakeholders. In addition, specific analytical approaches were selected for certain areas in order to capture the required balance between user group needs and ecological features of the system. The use of material flow accounting methods in the highly urbanized Gauteng urban assessment (SAfMA Gariep), where management scales are localized but ecological resources are external to the assessment scale (that is, are imported), was one way in which management and ecological scales were matched. In addition, both SAfMA and Portugal matched designs with levels of available or collected data. SAfMA Gariep, for instance, assembled a user group that reflected a combination of national, provincial, and local authority stakeholders involved in the management of the Gariep Basin.

4.4 Assessing Benefits and Costs of Multiscale Assessments

This section examines the information and impact benefits and costs of the multiscale approach.

4.4.1 Information Benefits and Costs

The information benefits highlighted by the sub-global assessment teams resulted primarily from increased communication and information flow among assessment teams operating at various scales of analysis; particularly beneficial was the improved information available from the local assessment processes. These benefits appear to be related to an increased sensitivity to local-scale perspectives, which influenced the underlying approaches to regional and basin-scale assessment activities. The specific benefits include:

- *Increased attention to social perspectives.* In the southern Africa assessment, greater consideration was give to social issues than originally anticipated. Initially, the pilot assessment derived patterns and processes responsible for food shortages based on a biophysical approach to the analysis of food, using variables such as food distribution as a function of infrastructure, production capacities of the environment, and demand as a function of population size alone. By incorporating local-scale perspectives, the full assessment of food and local livelihoods issues permitted the incorporation of local-scale problems of access to food, synthesizing data from a meta-analysis of 50 on-the-ground case studies of food insecurity at the local level in southern Africa (SAfMA). Together, these perspectives provided more detailed and locally relevant data on food security than initially envisioned. (See Chapter 11.)
- *Framing of results and conclusions.* The multiscale approach resulted in increased attention to the likelihood that regional findings may not adequately reflect sub-regional differences due to the use of analytical methods that tend to neglect local heterogeneity. For example, SAfMA originally intended to present fuelwood availability in terms of production and demand models in order to identify areas of excess and deficiency. Instead the data were discussed in a more nuanced way: areas of fuelwood excess when examined from a regional scale may well contain local areas with severe shortages; similarly areas of overall shortage may contain locations with sufficient fuelwood supplies.
- *Increased awareness of stakeholder needs.* The multiscale approach helped to focus findings on the needs of decision-makers at the scale of each component assessment. A regional-scale report will not necessarily speak to local-scale stakeholders. The perspectives and issues addressed are those of relevance and importance to regional or national decision-makers; other perspectives and issues may well have to be adopted and addressed to be meaningful to local-scale decision-makers.

The data requirements of an assessment depend on what specifically is being analyzed, and a multiscale assessment that integrates various levels of analysis necessarily requires the appropriate data sets. A wide body of data could be brought to bear on efforts to conduct multiscale assessments. However, the available information is often in a nonscientific format and must be processed for use in an assessment (for example, Gariep Basin). Moreover, the assessment may require not only data along spatial dimensions, but also data collected along a temporal dimension (that is, historical data) for a richer representation of the ecosystems analyzed. Developing a representative temporal data set for any area is a difficult task that is constrained by data availability and quality.

Even where large ecological and social data sets are available, there is often a mismatch among formats that makes the analysis of these joint data sets difficult, if not impossible. The design criteria of data independence across multiple scales in SAfMA precluded certain data-sparse regions from analysis, such as the areas of the Gariep Basin that extend into Namibia and Botswana. Data acquisition for these regions would have required the use of larger regional or global data sets and would have compromised the design criterion of scale data independence (SAfMA Gariep).

Additionally, an effective assessment involves interactions between the experts and the users of the assessment. The focal questions addressed in an assessment, and the scale of analysis used to address those questions, is dynamic and may change somewhat during the course of an assessment. Several MA sub-global assessments experienced this process of "adaptive scaling." For example, in Tropical Forest Margins, the scale of analysis was expanded during the course of the assessment from an initially highly local focus (for example, assessing the impact of burning when clearing agricultural land on soil nutrients) to include meso-scale assessments of smoke pollution and the implications of forest patchiness for biodiversity, and macro-scale assessments of carbon sequestration. The original design did not completely engage all users, and needed to be expanded to meet user needs.

4.4.1.1 Improved Analysis of Scale-Dependent Processes, Cross-Scale Interactions, and Causality

The most important drivers of ecosystem change identified in the various sub-global assessments differed across scales of analysis. (See Chapter 7.) For example, at a local scale, the frequency of droughts was considered a critical indirect driver of ecosystem change (since it affects water management strategies and agricultural production systems, which are seen to be the direct drivers of change). At coarser spatial scales, climate change was considered a key direct driver of ecosystem change (since it is a result of other indirect drivers such as per capita energy consumption) (SAfMA Gariep). Such a shift in emphasis about the role of drivers is typical of hierarchical systems but also emphasizes the different ways in which a single driver can manifest at different scales. This phenomenon is important when considering the most appropriate responses or policy interventions for mitigating impacts on ecosystem services at various scales. Further evidence for the changing nature of ecosystem drivers was offered by the Portugal sub-global assessment:

> *At the local scale it is usually very clear what the most important direct drivers of ecosystem change are, and how those drivers are going to evolve in the short term. This assessment is more difficult at the national scale. Some ecosystem services are also scale-dependent. For instance, a forest bordering a basin can*

play an important role in the water cycle, but this role only becomes apparent at the basin scale, not at the local scale. (Portugal)

The changing set of causal factors of tropical deforestation was also highlighted in the Tropical Forest Margins sub-global assessment. In this case, the assessment team noted the various scales of drivers for observed patterns of deforestation:

Shifting cultivation for subsistence food production is seldom the main cause of tropical deforestation. Other forms of agricultural expansion—practiced by smallholders and large landowners alike—tend to be much more important. But the most significant determinant of all is how these land uses interact with, and are affected by, macroeconomic forces, access to markets, and a host of other policy and institutional factors. (Tropical Forest Margins)

4.4.1.2 Reliability and Accuracy of Findings

The initial expectation, that drawing from views at multiple scales would yield a progressively better understanding of the relationship between ecosystem services and human well-being, was borne out in the sub-global assessments. Already mentioned is the SAfMA experience that incorporating local scales into the assessment increased heterogeneity in the identification of food shortages. Another example is that regions identified in the MA global assessment as suffering from water shortages were confirmed in finer scale assessments (see Chapter 8), thereby providing considerable support for the findings of each assessment (for example in SAfMA Gariep, San Pedro de Atacama, India Urban, Western China, and Laguna Lake Basin). In contrast, should the areas of water scarcity identified change across scales, assessment teams would be compelled to explore the possible reasons for such discrepancies, such as data or model inaccuracies, or alternative livelihood strategies that nullify broad-based patterns (for example, access to subterranean water sources in areas that possess limited surface water). In summary, the degree of confidence in the conclusions drawn from an assessment can be determined by the degree of consistency of findings (spatial or temporal) between assessments at different scales. Where a *comprehensive* multiscale assessment is conducted, the confidence in identified relationships and patterns across scales, whether positive or negative, is strengthened.

4.4.2 Impact Benefits and Costs

The primary goal of the sub-global assessments was to meet the needs of decision-makers at the scale at which they were undertaken, and in so doing, to inform and influence policy, management, behavioral, and institutional decisions. Given the status of the sub-global assessments, many of which are still in their implementation phase, it is not possible to judge what their final impact will be. This discussion therefore focuses on the ways in which conducting multiscale analysis facilitates an assessment process, rather than its potential impact. Even for the completed assessments, it is still too early to offer insights into the degree to which assessment outcomes will be incorporated into users' decisions-making processes.

4.4.2.1 Relevance of Problem Definition

For assessment findings to apply to a specific locality requires not only that information be collected and disseminated at a local scale, but also that local stakeholders be afforded the opportunity to target assessment questions to their specific needs. This proved particularly important in the face of varied definitions of human-well being at the local level. (See Chapters 5 and 11.) Participatory methods to generate an indigenous perspective on ecosystem services in Bajo Chirripó, for example, prompted the assessment team to focus on the well-being needs of local communities. This required that the analysis and results be presented in a fashion consistent with the world view of those communities, including due consideration of (1) the view that human beings are an integral part of habitats and habitats are part of human beings; (2) the belief that reciprocity exists among human beings (men–women, children–elders) and with the environment; and (3) the idea that the respect granted all of society is based on codes, norms, myths, beliefs, and dreams (Bajo Chirripó).

Similarly, increased relevance to local people was also attained within the Gariep Basin assessment, which initially paid little attention to the ongoing HIV/AIDS epidemic beyond its potential impact on demographic parameters. It soon became clear through interaction with the user group, however, that the social ramifications of HIV/AIDS were of paramount importance and should be more explicitly addressed in the assessment. A lack of attention and responsiveness to such identified needs would have had serious consequences for the legitimacy of the report in the eyes of the user community (SAfMA).

4.4.2.2 Relevance of Assessment Findings

The acid test of any assessment is the degree to which society ultimately assimilates the results of the assessment into its regulatory frameworks and livelihood practices. However, there is frequently a temporal mismatch between the time frame for decision-making (days to months) and the time frame for the research and assessment that may be needed to adequately inform decisions (years). Assessments play a valuable role in assimilating large bodies of recent scientific information in a more useful form for policy-makers. Many decisions can be taken even in the absence of full information and understanding; for example, a decision-maker might act to put in place a monitoring and management system for a previously unmanaged ecosystem service even before full information about that service is available. The proactive approach taken by the MA is therefore appropriate, as it attempts to anticipate the requirements of decision-makers. The pursuit of a U.N. resolution to create an appropriate international management framework for the Caribbean Sea is a case in point (Caribbean Sea).

Whether a user or decision-making community has the ability to respond to assessment outcomes is significantly influenced by that community's overall understanding of the nature of the problem and whether opportunities for action existed prior to the launch of the assessment. Where the community is well-informed, an assessment may be able to provide specific information that can directly shape decisions. In contrast, when the issues are not familiar to the user community, the assessment may serve primarily as a tool for increasing overall understanding and awareness of the problems and options for responding. For example, the scientists and administrators involved in the Southern Africa assessment readily understood that climate change was a driver of change in the ecosystems in the region, but this was not known, and came as a surprise, to some of the local communities (SAfMA Gariep). These different perceptions and levels of understanding stem from differences in access to information among sectors of society, often within the same communities; in Bajo Chirripó, for example, young community members held views about ecosystem services that were very different from those of their village elders. Moreover, the ability of the general public to absorb novel information may be very slow.

4.4.2.3 Benefits of Scenarios Analysis

The benefits of designing scenarios at multiple scales are outlined in detail in Chapter 10 of this volume. The construction of scenarios at multiple scales allows an assessment to focus on the key uncertainties most important to stakeholders at a particular level. Key uncertainties at the global scale are not necessarily the most important uncertainties for decision-makers in a particular region or community, nor are the time scales that are typically considered at the global scale (50–100 years) very meaningful to decision-makers at the local community level. For example, a key uncertainty considered by the MA Scenarios Working Group at the global level was the degree to which technology can serve as a substitute for ecosystem services over the next 50 years. Within the southern African region, this was considered a relatively unimportant question within the 15–30 year time period of interest to local and regional decision-makers. The key uncertainty with respect to ecosystem services in southern Africa over the next two to three decades was identified as the effectiveness of governance in the region. It is interesting that governance emerged as a key uncertainty at all scales of the southern Africa assessment, although the particular form differed by scale. In SAfMA Regional, the key uncertainty revolved around national and transboundary governance structures and processes. At the local community level, the uncertainty centered on the effectiveness of municipal and community level governance (SAfMA Livelihoods, SAfMA Gariep). In general, key uncertainties of interest and importance tend to differ by scale.

4.4.2.4 User Ownership and Capacity Building

The sub-global assessments developed a number of design strategies to increase user confidence in the assessment findings. These strategies included:

- *Focusing on the local level.* One benefit that an assessment can provide is to contribute to repairing the broken trust between local communities and other stakeholders. The assessment's contribution is in providing relevant scientific information on key issues of importance to users. In San Pedro de Atacama, for example, where global demand for minerals and national demand for tourism revenue collide with local needs for reliable water supplies, the project design chose to bolster the ownership benefits of the assessment at the local level.

  Given the existence of clear and defined bodies of political decision-making in the different scales identified, the project decided to concentrate on and collaborate with local institutions, in order to strengthen their potential impact on the decisions the project might influence. This decision was also motivated by the local community's growing distrust and conflict with both the public and private sector. It was therefore considered more important to strengthen existing organizations, rather than create new ones, and so contribute to increasing awareness of the environmental issue in the very heart of such institutional arrangements. (San Pedro de Atacama)

- *Providing a multistakeholder forum where public and private actors jointly discuss important issues for the assessment area.* This can be done by incorporating representatives from various agencies and interest groups into the advisory board of the assessment. In the Laguna Lake Basin assessment, this approach was used to include key people in a position to most effectively generate appropriate interventions and mitigation actions (KM–Laguna Lake Basin). Similar measures to increase the network and communication links among relevant stakeholders were utilized in a Swedish sub-global assessment:

  The central actor—EKW at the municipal level—has chosen to limit its concern to the social-ecological system at the municipal scale. A catchment scale would appear more logical but EKW did not have the political mandate, nor the resources, to initiate a collaborative learning process for ecosystem management at that scale. Now that we (Stockholm University) are part of the network we might be able to broaden the social-ecological scale. (Sweden KW)

Increased understanding of multiscale interactions resulted in increased awareness that sectors of society operating at different spatial and temporal scales often place competing demands on ecosystem services. In practice, this means that difficult trade-off decisions have to be made in terms of allocating limited resources to serve multiple human needs. Negotiated solutions to environmental resource tensions are not always easy to achieve, and power relations among various groups may be significantly skewed. In several cases, the ecosystems upon which communities depend are being systematically exploited by more powerful agents (Coastal BC, PNG, San Pedro de Atacama). The collapse of abalone populations along the coast of British Columbia is a case in point: when breeding locations, sustainably harvested for generations by First Nations, were opened to commercial fishing interests, it led to a total collapse of this ecosystem service (KM–Coastal BC). Although it is often argued that such large developments often serve the greater good, for example, regional development and/or national economic gains, communities involved in the sub-global assessments often did not share this view. (See Chapter 11.)

4.4.2.5 More Balanced Assessment Results

Based on the experience obtained to date in the uptake of assessment findings, there is evidence that a multiscale structure did improve the impact of assessment results by more directly meeting the user needs of specific areas. For example, in the southern Africa assessment:

> *The larger scale studies provided the broader context for some of the findings at smaller scales, while the smaller scale studies served to ''ground-truth'' regional findings and provided more detailed understanding of some of the broader scale findings. In addition, different scales contributed an understanding of different processes (e.g., it is meaningful to study fuelwood at the regional and local scales, but less so at the basin scale), or alternative views of the same process as seen differently by stakeholders at different scales (e.g., ecotourism at the regional as opposed to the local scale). (Scholes and Biggs 2004)*

4.5 Lessons Learned in Conducting Multiscale Assessments

The various sub-global assessments explored here were derived from distinctive needs, interests, and capacities; undertaken at different locations and over different time frames; and involved different stakeholder groups. The scales of analysis and systems of observation selected were uniquely shaped by the circumstances and people involved in each assessment. Perception is key, but so are the spatial and temporal scales through which perception is achieved and analyzed. The sub-global assessments thus came to combine scales of observation and scales of analysis, often in mutually informative ways. (See Box 4.5.) This iterative process of conducting an assessment at multiple scales was highlighted in the Tropical Forest Margins sub-global assessment report:

> *In some cases, this process of identifying the appropriate scale for analysis and reporting has been a research activity in itself extending over a period of several years. (Tropical Forest Margins)*

Although the sub-global assessments represent a wide variety of environmental and socioeconomic conditions, the lessons learned from conducting assessments under a common conceptual framework at each of these sites offered valuable insights about the design and implementation of a multiscale assessment. Additionally, the MA sub-global assessment experiment generated a wide range of innovative ideas, as well as lessons and pointers toward best practices that could be useful for conducting assessments in the future. (See Chapter 6.) Best practices are discussed throughout this volume; however, the unique nature of multiscale assessments offers additional insights and solutions that are peculiar to a multiscale assessment. The following sections synthesize the lessons learned across the sub-global assessments in conducting multiscale assessments and offer a discussion of methodological innovations for conducting an assessment at multiple scales that emerged from the assessments.

4.5.1 Conducting Multiscale Assessments

The MA conceptual framework assumes that the continued provision of ecosystem services requires mutually supportive responses at multiple levels and that, in general, effective management of ecosystem services requires responses at many different scales (MA 2003). This perspective was confirmed in the Southern Africa assessment:

> *The different scales were chosen to make it possible to investigate processes at the scales at which they take place; to take into account feedbacks between scales; to help ensure that perspectives at any given scale are reflected in the analysis and conclusions at other scales and to allow evaluation of the scale dependence of various actions and policies and to meet the needs of different users. (Biggs et al. 2004)*

Conducting a multiscale assessment presents a significant challenge for several reasons, including difficulties associated with bringing together multidisciplinary teams, issues related to data availability, methodological challenges, and a lack of integrative scale-independent theories. The task of an assessment team is to choose a set of focal scales that correspond best with the key concerns of the study area by considering the following:

- user needs at different scales,
- local context and extent of ecosystem services considered,
- assumptions about the nature of the relationships between observed patterns and the drivers of change in the assessment area, and
- available data and time constraints.

Given the difficulties that must be addressed in a multiscale approach, the collective experience of the sub-global assessments indicates that there are some times when a multiscale assessment is absolutely necessary. At other times, however, even though a multiscale approach or analysis would provide useful informtion, it is not necessarily required to achieve the desired outcome. Making this a priori decision is difficult, but the inclusion of at least one scale of analysis (the scale most relevant to the dominant ecosystem services and decision-making levels) between global and local assessments generally appears to be beneficial.

A multiscale approach can be considered absolutely necessary under any of the following conditions:

- when the relevant definition of the problem assessed and/or the specific objectives of the project dictate a multiscale approach;
- when response and policy-prescriptive mechanisms for coping with changes to ecosystem services depend on syntheses and theories that link data from various scales of analysis into a coherent picture of how to better manage ecosystems for human well-being;
- when understanding causality and/or who wins and loses under current circumstances (or under possible policy options) is important to the users of the assess-

BOX 4.5

Multiscale Assessments: Some Emergent Challenges

Multiscale interactions, although understood to be important, present significant scientific challenges in both observation and explanation. The MA provides a valuable comprehensive review of these issues (MA 2003). Theories of observation have profound histories in philosophy, statistics, and linguistics, each of which has focused in its own ways on how people create categories to distinguish among measurable realities they perceive to be significantly different from one another. Because such categories change, even for one person, with context, mood, technology, need, and purpose, the choice of any one category necessarily precludes the informational opportunities available if categories, scales in this case, were chosen in another moment or place or with different tools and purposes. To one extent or another, the observation embodies the observer and the conditions shaping the observer's perception.

The scientific challenge is to identify, reduce and even eliminate the bias this introduces to observations. Theories of statistical sampling, language formation, and econometrics, among others, provide particular insight into the complexities of the problem and ways to overcome them. Today advances in measurement techniques and computational capacity are enabling the generation of numerous differently scaled observations, simultaneously and over time, and their use in iterative searches for patterns of relationship that emerge within and among observational scales.

Hierarchy theory, which is one current body of knowledge upon which the MA has relied to assess cross-scale processes, is restrained by observational limits. But if such limits did not exist, there are even more formidable problems in the measurement and explanation of processes which, as contrasted with objects, are intrinsically mobile and therefore particularly prone to distortion when efforts are made to hold them still, however momentarily, for a look. Moreover, processes are themselves identified by categories of the behavioral theories (for example, adaptation and evolution) that define them as significantly distinctive behavioral relationships.

Today, such explanatory challenges have created a new scientific openness to the wide variety of modes of explanation existing throughout the world. Interdisciplinary and cross-cultural inquiry, such as the MA has fostered, perhaps on a uniquely ambitious scale, is one part of this development. So, too, is the empowerment of discussion about modes of explanation that have developed outside the culture and interests of the Western scientific tradition.

For the MA sub-global assessments, user concerns, needs, and data availability defined the changing set of scales of observation and explanation among the assessments, and within assessments over time. This reduced opportunities for comparability and meta-analysis while revealing the immense observational and explanatory variability that exists over the world and that a global assessment alone would not capture. In the future, perhaps the emerging richness of observational method will be joined by equivalently rich mobility among conceptual frameworks and the processes it can begin to reveal and explain.

ment. For example, a global assessment is sufficient to identify whether humans have an impact on stratospheric ozone. However, to understand which countries are causing the problem or to understand who is most at risk from depleted ozone concentrations, a multiscale analysis would be essential; or

- when the presence of assessments at multiple scales will significantly increase the ownership of the assessment findings by users at those scales.

Even though a multiscale approach may be potentially informative, it is not always necessary to achieve desired outcomes. Many sub-global assessments produced information useful to their stakeholders without carrying out a multiscale assessment or undertaking multiscale analyses. This was the case either:

- when the costs (in monetary terms or in terms of the difficulties) outweighed the potential benefits to be gained from conducting an assessment or analyzing information at multiple scales; or
- when a single scale of analysis best corresponded to the problems, objectives, and/or decision-making structures of the assessment. For example, the Kristianstad Wetlands assessment focused on a localized geographical problem that did not require extensive regional analysis to achieve the required outcome (Sweden KW).

These points notwithstanding, the evolving nature of the sub-global assessments may at some point in time require the incorporation of additional scales of analysis into the assessments. As data become increasingly available, more widespread and efficient analyses will likely develop. Indeed, many sub-global assessments indicated explicit intentions of scaling up the assessment process in the future (KM–India Local, Vilcanota, Colombia).

4.5.2 Evolving Scale-related Issues

When there is an obvious need for a multiscale assessment, and the multiscale design has been agreed upon, a number of issues need attention when conducting the assessment:

- *Evolving user needs.* User needs are not static, even over short time scales. The assessment needs to provide opportunities for users to engage with the assessment at regular intervals to accommodate this dynamic and to re-assess user needs as necessary.
- *Emergent mismatches.* Irrespective of how carefully an assessment is designed, the designs may not always turn out to be practical, and surprises may crop up, requiring some flexibility and adaptation. Tropical Forest Margins found the initial assessment scales to be insufficient for capturing important drivers relevant to understanding tropical forest conversion; the assessment strategy was subsequently adapted to incorporate these drivers.
- *User engagement.* The need for active user engagement increases as assessments become more fine-grained and are more intimately involved with the needs, aspirations, and dynamics of local communities. This process of user engagement can be extremely time-consuming and resource-intensive. Time constraints made it challenging to maintain the required user group and stakeholder involvement while conducting sub-global assessments. For a comprehensive discussion of the requirements, dynamics, and examples of an effective participatory process in environmental science, see Younge and Fowkes

(2003). This feature of incorporating effective stakeholder engagement models in assessments is one that needs to be improved in future assessments.

4.5.3 Multiscale Sub-global Assessments as a Source of Innovation

The sub-global assessments were important sources of innovation in conducting multiscale assessments, prompting both new analytical tools and new institutional response mechanisms.

The sub-global assessment experience emphasized the need for tools and approaches to deal with issues at widely differing scales, as well as for integrating across scales. It also suggests that it is feasible to develop analytical methods that not only are consistent with the goals of a multiscale assessment, but that can also significantly enhance the multiscale assessment process over space and time. SAfMA, for instance, developed a scale-independent index (the Biodiversity Intactness Index) to measure and compare biodiversity across the various scales of analysis. (See Box 4.6.)

A number of sub-global assessments developed innovative institutional response mechanisms. (See also Chapter 9.) While some sub-global assessments viewed broadly defined ecosystem management initiatives such as the Convention on Biological Diversity as remote mandates requiring relatively few responses at the local level, others saw these initiatives as opportunities to develop innovative and cooperative response arrangements, for example, between villages, state agencies, indigenous groups, international and national NGOs, and corporations, in combination with distinctive places, problems, and political cultures. The People's Biodiversity Register, developed in response to the CBD by India Local, is a case in point. Other examples include San Pedro de Atacama, Laguna Lake Basin, Sweden KW, and Sweden SU. Although innovations were initially developed at localized scales, they are beginning to transform the way societal response management options and impacts are viewed at coarser levels (India Local, Caribbean Sea). What this means for organization, knowledge, and technologies for the future management of ecosystem services deserves further consideration.

4.6 How Do Sub-global Assessment Results Inform Global Assessments?

The extracts and examples provided thus far from the sub-global assessments have important implications for a number of scale-related findings, hypotheses, and statements generated from a global assessment perspective. Evidence from sub-global assessments that inform global findings are highlighted below; they emphasize that drawing from both views (global and sub-global) presents an opportunity to gain a progressively better understanding of the role of ecosystem services for human well-being.

Global forces, local impacts. The sub-global assessments found that global forces significantly affect the magnitude and quality of ecosystem services through all scales of human activity down to farm and household levels (Caribbean Sea, Northern Range, San Pedro de Atacama, SAfMA Gariep, Tropical Forest Margins). Particularly influential are global markets, trade, climate and human activities affecting it, and shifts in the global political order from the bipolar world order (rich–poor, industrial–developing) toward diffused and regional representations.

Climate variability, climate change, and biodiversity risk avoidance. The sub-global assessments, almost unanimously, recorded concerns about the threats of climate variability and climate change, and of these, almost half also documented concerns about threats to biodiversity and the livelihood consequences for people (India Local, SAfMA Gariep). This concern is shared with the global assessments that emphasize the importance of risk avoidance in managing ecosystem services. This suggests that concerns about climate variability and climate change and biodiversity loss are pervasive among people from all walks of life, even those that operate at very different scales. This means that the fulfillment of the Kyoto agreement and CBD aspirations has broad relevance across scales.

Food production trade-offs, risk, threats, and insecurity. The importance of the fundamental trade-off between the need to increase food production and the need to sustain, in the long run, the capacity of ecosystems to support food production is enriched by further trade-offs that gain particular importance at sub-global and local scales. These trade-offs exist:

- between the needs to increase food production and to secure a minimum livelihood in uncertain market, climate, and political conditions (Argentine Pampas, Tropical Forest Margins);
- between the needs to increase food production and to distribute it to secure minimum needs (Altai-Sayan); and
- between equitable distribution of food and the sustainability of environmental productive capacity (SAfMA Gariep).

Evidence from the sub-global assessments suggests that people devalue the consequences of their actions on future generations or other scales when their security of life and livelihood is threatened and that people are likely to avoid commitment to altered resource management regimes if they perceive their returns as vulnerable or variable (Caribbean Sea, Tropical Forest Margins, SAfMA Gariep). Such perceptions have obvious implications for developing appropriate responses to agricultural resource degradation at a local scale where immediate needs have to be addressed explicitly.

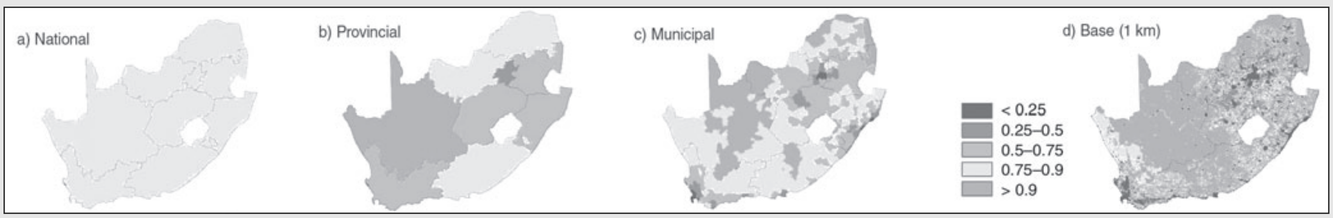
Evolution of governance arrangements and institutional responses. The sub-global assessment results showed that effective institutional and governance arrangements evolve in response to site- and culture-specific conditions and extreme events for a whole range of ecosystem services, from forests, water, and soil to the resolution of urban land use conflicts (Sweden KW, Sweden SU, San Pedro de Atacama, Colombia, Vilcanota, KM–Laguna Lake Basin). This expands on the MA conceptual framework's view that institutions are primarily mechanisms for implementing policies, not emergent responses in their own right (MA 2003).

BOX 4.6

Assessing Biodiversity at Multiple Scales: SAfMA

The MA considers biodiversity—the total variety of life at the genetic, species, and ecosystem levels (MA 2003)—as a condition necessary for the "delivery of ecosystem services" by virtue of the many feedbacks that exist between biodiversity and global environmental and biophysical variables (Brown and Maurer 1989; Chapin et al. 1998; Kleidon and Mooney 2000; Zavaleta et al. 2003). The extent to which biodiversity contributes to the delivery of ecosystem services for human well-being depends on the relationships between a complex set of factors (climate, geomorphological processes, etc.) operating simultaneously at various scales. The currency of these relationships includes biomass, water, trace gas exchange, plant and animal movements, and productivity (Botkin et al. 1984). Certain ecosystems may serve as sources of materials or energy, while others may serve as sinks (Pulliam 1988). Information on the state of biodiversity is therefore of importance to policy-makers concerned with managing ecosystem services. Existing measures of biodiversity, in particular species richness, are heavily scale-dependent, making it difficult to compare results at different scales.

SAfMA developed a new index of biodiversity condition (the Biodiversity Intactness Index) to assess changes in species abundance at the different scales of the assessment (Biggs et al. 2004). The index, represented below at three special scales (national, provincial, and municipal), aggregated from the base resolution of 1 kilometer (d), permitted direct comparison among results obtained at different scales (extent and resolution) of analysis. The index can be applied using species richness (distribution) data of varying resolution; it is robust to reasonable differences in the interpretation of land use classes.



The Biodiversity Intactness Index applied at sub-national levels of environmental decision-making in South Africa. The overall score for South Africa is 81.2%. Results are richness- and area-weighted averages of BII as estimated at a base resolution of 1 × 1 km. Values of BII obtained at different scales are directly comparable: they refer to the average abundance of all species in the particular area, expressed as a fraction of pre-colonial era abundance. (Biggs et al. 2005)

In addition, the sub-global assessments showed that management increasingly involves not just a local group and the government, but a range of stakeholders that acknowledge overlapping systems of management and diverse interests. This applies to institutional responses across sectors as diverse as water (KM–Laguna Lake Basin), watershed management (SAfMA), biodiversity (India Local), and metropolitan management (Sweden SU, KM–São Paulo). In other words, cross-scale institutional processes are much more common than might be expected from a single-scale assessment and may well be the means through which the variations in climate and markets are absorbed and risks are spread to secure effective commitments to problems of ecosystem services and human well-being.

The role of markets, trade, and the environment at the local level. Some sub-global assessments indicated that people are primarily concerned with avoiding risks that threaten their security and livelihoods (SAfMA Gariep; Tropical Forest Margins; KM–Bajo Chirripó; Alejandro Argumedo, personal communication, Vilcanota). This could explain the emergence of local decisions that at first glance appear to contradict economic predictions. For example, local communities will protect sacred groves as species reservoirs through exploitation taboos in the face of economic hardship or famine—a risk-avoidance mechanism that ensures continued access to these species in the future (SAfMA Gariep).

Moreover, the sub-global assessments revealed penetrating influences of market price relationships on human activity and ecosystem services (PNG, San Pedro de Atacama, SAfMA Gariep). Emanating from integrated global commodity markets, these relationships guide local crop and natural resource management choices (Coastal BC, Portugal, SAfMA Gariep, Tropical Forest Margins, Colombia), distributions of intensive and extensive activities (SAfMA Gariep, Tropical Forest Margins), and balances between the build-up and drawdown of environmental capacities. For example, significant declines in crop prices (due to combined effects of global commodity price changes and changes in currency values) can lead to rapid changes in land use practices. This dynamic was evident in the case of coffee producers in Colombia, where the market value for coffee plummeted from $2.00 per pound in 1986 to $0.64 per pound in 1987. People shifted from coffee production to cattle ranching, expanding the production areas into sensitive ecoregions (resulting in 19% and 25% reductions in forests and the fragile ''paramo'' ecosystems, respectively) (Colombia).

Changing market conditions, combined with increased availability of employment alternatives, can also result in a shift of labor away from traditional resource management activities. This labor mobility can harm local ecosystem services (for example, if smallholder farmers move to cities and sell unwanted land for use in intensive agriculture). Or it can enhance ecosystem services if it leads to a reduction in harvest pressure on a natural resource (such as reducing fishing pressure). In the Downstream Mekong and Bajo Chirripó sub-global assessments, the negative impacts predominated. In Viet Nam, for example, conversion of mangroves to shrimp farming has increased local incomes, but at considerable cost to these ecosystems (Downstream Mekong).

Local processes, global impacts. The sub-global assessments highlighted a number of instances where local factors (such as responses and drivers) can achieve global significance, although time lags (that is, the time it takes for these forces to be noticed at coarser scales) and market mechanisms may obscure this process. In some sub-global assessments, such processes have begun to facilitate cross-scale sharing of knowledge and information, largely through initiatives by civil society to influence national and even regional or global agendas. The Caribbean Sea assessment team's pursuit of a U.N. resolution to designate the Caribbean Sea as an area of special importance is a case in point. In this case, the needs of local land users in independent countries (in the tourism or fishing industries, for example) were aggregated to achieve special consideration by a global body. Plans to protect the species listed in India's People's Biodiversity Register under the umbrella of intellectual property rights are another example of a local process that can achieve global relevance. What these sub-global examples imply is that the capacity to develop appropriate responses to changes in ecosystems can and often does emerge at very local scales—but their potential impacts may also be felt at much coarser scales.

Uncertainty. The sub-global assessments demonstrated the prevailing influence of uncertainty and insecurity as a driver of human actions across all spatial and social scales (SAfMA, Tropical Forest Margins, Northern Range). Individuals are more likely to invest in long-term sustainable management of a resource under conditions where they have relatively high confidence that those investments will provide a return. This in turn requires relatively stable commodity prices, secure rights to resources, and a predictable regulatory and institutional structure. One factor influencing the perception of uncertainty and insecurity is the knowledge of local climate and ecosystem processes. Individuals with considerable local knowledge about variations in climate or ecosystem processes may perceive far less insecurity in standard environmental fluctuations than individuals without that local knowledge. Uncertainty and insecurity are thus key factors shaping the responses of individuals and communities to ecosystem changes. An appropriate response thus cannot be developed based only on projected future trends; instead stakeholder perceptions of uncertainty also need to be gauged and managed.

Global political order and emergent innovations. Two global political trends appeared to be important in all of the sub-global assessments. The first involves the tensions inherent in the reality of today's bipolar (rich versus poor) world order, and the ensuing diffusion and regionalization of power (trade blocs) (see PNG, San Pedro de Atacama, Coastal BC). Second was the emergence of nongovernmental interests as agenda-setters on a global stage, exerting significant influence on issues such as climate change, biodiversity, forests, water, and endangered species. In effect, ecosystem services are emerging as a unifying force on a global scale, while traditional forms of unification (for example, nationalism) are declining. The consequences for ecosystem services remain uncertain.

In sum, the diversity among sub-global assessments in terms of problem definition, objectives, scale criteria, and systems of explanation increased as the focus on local scales of assessment increased. Processes and issues of common concern assumed different meanings and implications at different scales. This was particularly apparent in three common areas of concern within all sub-global assessments:

- *market forces,* which at global scales govern broad allocations of resources, such as the increase or decrease of forest cover, but at localized scales determine livelihood strategies, security, and protective organizational, technical, employment and migration responses;
- *environmental degradation,* which at global scales addresses phenomena like climate change and biodiversity loss but toward local scales becomes increasingly tied to a complex web of trade-offs associated with the provision of ecosystem services upon which livelihoods depend; and
- *perceptions and uses of institutional channels* through which ecosystem services might be enhanced, from global agreements and financial commitments to cooperative local resource management and indigenous advocacy.

Comparison among scales of an apparently common problem produced a much richer sense of the problem and how to respond to it.

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