Chapter 10

Sub-global Scenarios

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Main Messages ***231***

10.1 Introduction **231**
10.1.1 Scenarios: Definition and Purpose
10.1.2 Scenarios in the MA Global Assessment
10.1.3 Scenarios in the MA Sub-global Assessments
10.1.4 Assessing Work in Progress
10.1.5 Analytical Framework and Organization of Chapter

10.2 Handling Uncertainties **236**
10.2.1 Key Uncertainties Identified in Sub-global Assessments
10.2.2 Describing Key Uncertainties after Identification
10.2.3 Relationships of Uncertainty to Ecosystem Services and Human Well-being

10.3 Telling Plausible Stories **239**
10.3.1 Diversity of Approaches
10.3.2 Frameworks Used to Develop Storylines
10.3.3 Systems Models, Quantification, and Spatial Explicitness

10.4 Incorporating Ecology into Scenarios **244**
10.4.1 Ecological Detail in Scenarios
10.4.2 Ecological Interactions and Surprises

10.5 Dealing with Scale **245**
10.5.1 Multi- and Cross-scale Processes in Scenarios
10.5.2 Spatial Extent, Heterogeneity, and Resolution
10.5.3 Time Horizons
10.5.4 The Linkage between Sub-global and Global Scenarios

10.6 Participating in Scenario Development **248**
10.6.1 Goals of Participation
10.6.2 Selection of Participants
10.6.3 Mechanisms of Participation
10.6.4 Roles of Participants
10.6.5 Problems Encountered in Participation

10.7 Communication in Sub-global Scenarios **250**
10.7.1 Communication Strategies
10.7.2 Scenarios in Policy Dialogues
10.7.3 Storylines for a Wider Audience

10.7.4 Spatial Representations of Scenarios
10.7.5 Community Theater and Video Techniques

10.8 Findings of the Sub-Global Scenarios 252
10.8.1 Commonalties among Scenario Findings
10.8.2 Comparing Findings across Scales
10.8.3 Summing Up: The Importance of Stakeholders

10.9 Conclusions and Recommendations for Future Assessments 255
10.9.1 Strength in Diversity
10.9.2 Lessons Learned

APPENDIX

10.1 Summary of Global Scenarios in the Millennium Ecosystem Assessment 257

REFERENCES 258

BOXES

10.1 Developing Storylines: The Caribbean Sea Approach
10.2 Nested, Multiscale Design: SAfMA and Portugal
10.3 Obstacles to Communication: Papua New Guinea

FIGURES

10.1 Key Questions Asked about the Design and Implementation of Scenario Exercises in Sub-global Assessments and Selected Answers to Four of These Questions
10.2 Two Sets of Uncertainty Axes That Could Be Used to Describe the Northern Highland Lake District, Wisconsin, Scenarios
10.3 Cascading Uncertainties in Social-ecological Systems That Might Be Captured in Scenarios
10.4 The Southern Africa Regional Assessment Scenario Development Approach
10.5 The Use of Soft-models as an Intermediate Step in the Forest and Agroecosystem Trade-offs in the Humid Tropics (Tropical Forest Margins) Scenario Exercise
10.6 Example of Spatially Explicit Scenario Outputs in the Southern Africa Regional Assessment

TABLES

10.1 Summary of the Scenario Exercises in Selected Sub-global Assessments
10.2 Major Exogenous and Endogenous Uncertainties across the Sub-global Scenarios
10.3 Steps in the Scenario Development Process
10.4 Reasons Given by the Sub-global Assessments for Excluding or Including Multiscale Considerations in their Scenario Exercises: Selected Examples
10.5 Reasons for Seeking Participation in Sub-global Assessment Scenario Development Exercises
10.6 Key Ecosystem Services Addressed in the Scenarios of Various Sub-global Assessments
10.7 Cross-mapping of SAfMA, Caribbean Sea, and Portugal Scenarios onto the MA Global Scenarios

Main Messages

Scenarios involve thinking about a wide range of futures, including both well-known trends and uncertainties. Developing scenarios is a fundamental prerequisite of strategic thinking and planning. Scenarios facilitate strategy formulation and evaluation, improve understanding of the uncertainties inherent in ecosystems, and test the robustness of particular strategies against a set of plausible futures. Unlike other decision-making techniques such as prediction, forecasting, and other single future outlooks, scenario-building is a cognitive and imaginative mechanism for decision-making. It uses more holistic, integrated, and participatory approaches to aid understanding of the intrinsic heterogeneity and uncertainty of ecosystem management. It also extends prediction and forecasting methods to provide additional and relevant alternatives to help decision-makers think, talk, plan and act imaginatively in pursuit of a more sustainable society.

Sub-global assessments used scenarios for multiple purposes, which often extended beyond the rationale for scenarios developed at the global level. Besides being used as a tool for decision-makers to plan for the future, many sub-global assessments, such as Southern Africa and the Northern Highland Lakes District of Wisconsin, also used scenarios as a means for communicating possible future changes and major uncertainties to stakeholders. In the assessments of San Pedro de Atacama, Chile, and Bajo Chirripó, Costa Rica, scenarios also have proved to be an important tool for acquiring data about stakeholder preferences, perceptions, and values. In a few cases, including Wisconsin, Caribbean Sea, and SAfMA, scenarios had a role in defining the boundaries within which discussions about management and policy options relevant to ecosystem services and human well-being could be held.

Despite being based on the MA conceptual framework, scenarios in the sub-global assessments differed greatly from the MA global scenarios. Significant differences between global and sub-global assessments in terms of key uncertainties, stakeholders involved, and scales of analysis, resulted in sets of sub-global scenarios that were different from the global scenarios. Nonetheless, a substantive link was maintained between global and sub-global scenarios in the case of the SAfMA, Caribbean Sea, and Portugal assessments.

Most sub-global assessments limited the discussions on which scenarios to develop around only one or two key uncertainties. Uncertainties were typically related to issues of technology, markets, and economic development; over half of the scenarios identified institutional arrangements/governance as a key uncertainty. Some unique examples of uncertainties included HIV/AIDS for Papua New Guinea, mining in San Pedro de Atacama, and the local legal system in India Local. Somewhat surprisingly, the Mae Chaem, Thailand, component of the Tropical Forest Margins assessment was the only assessment to explicitly address uncertainties surrounding ecosystem feedbacks.

Qualitative rather than quantitative models were most often used to explore interactions between major processes and structures, in order to provide a framework within which scenario storylines were developed. There is little documented explanation of the methods by which narrative storylines were developed in most sub-global scenarios. Many sub-global assessments noted the desire to quantify storylines, but time constraints and the lack of available models or expertise prevented all but Western China, Tropical Forest Margins (Mae Chaem, Thailand component), and SAfMA Regional assessments from undertaking such analyses.

Important scientific advances have been made in constructing nested scenarios at multiple scales. To meet the objectives of decision-makers and stakeholder groups with interests at different scales, the SAfMA assessment undertook five local-scale assessments that were nested within two basin-scale assessments, which were in turn nested within a regional-scale assessment. The Portugal assessment was also undertaken at three scales—local, basin, and national—though the local case studies were not nested within the basins that were assessed.

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

The scale and context of a sub-global assessment are primary considerations when selecting media for communicating the findings of scenarios. Specific contextual factors include the size of the audience, their level of literacy or formal education, their religious and cultural beliefs, and the cost of reaching the audience given available resources. Specific contexts have generated some unique and creative solutions including the use of theater in SAfMA Local Livelihoods and cartoon animation in Wisconsin.

Identification of winners and losers in each scenario is an important step in guiding future responses. The inclusion of stakeholders in the scenario development and validation process helps make explicit the circumstances under which winners and losers emerge. Sub-global scenarios highlighted the importance of scale in determining winners and losers. In the Portugal assessment, one local scenario was characterized by the abandonment of agricultural fields and rural–urban migration, which is undesirable to local policy-makers. However, this scenario could be nested within the MA's Global Orchestration scenario (developed as a part of the MA's global assessment), which is characterized by economic growth and viewed by the policy-makers at higher levels as having the highest net benefits for human well-being.

Future scenario activities need to pay even greater attention to ecosystem processes. Past and current scenario work has emphasized human activities as the main drivers of change in the availability of ecosystem goods and services, without much reflection on the implications of ecological feedbacks for ecosystems and human well-being.

The large and growing number of sub-global assessment scenarios is a unique source of information within the multiscale assessment context of the MA. The sub-global scenarios, employing the common conceptual framework of the MA, allow for the critical evaluation of local variation. It seems likely that the incorporation of the findings from sub-global scenarios into the MA's global assessment would have been valuable. However, because of timing issues, the global MA scenarios did not have the opportunity to incorporate the findings of the sub-global assessments.

10.1 Introduction

The MA scenarios, unlike some earlier scenario efforts, were developed to integrate ecology into their design explicitly (Bennett et al. 2003; Peterson et al. 2003a). Ecosystems are not treated solely as passive recipients of impacts resulting from changes driven by socioeconomic systems, but are understood to play an active role in jointly determining the futures of humans and ecosystems. Changes in

the flow of ecosystem services are seen as having the potential to alter future development pathways. This is a more integrated view of how human–environment systems unfold over time than is typically assumed in scenario exercises where the goal is to assess environmental changes. (See MA *Scenarios,* Chapters 2 and 3.)

The purpose of this chapter is two-fold. First, the chapter aims to critically review how scenarios were used in the MA sub-global assessments. For those interested in conducting or designing their own sub-global assessments, it points to both the limitations and strengths of the different approaches taken. Second, the chapter aims to draw some more general conclusions, for a broader audience, on how future assessments involving scenario exercises can incorporate ecological considerations.

10.1.1 Scenarios: Definition and Purpose

A scenario is a story that offers an internally consistent and plausible explanation of how events unfold over time (Gallopín et al. 1997; Raskin et al. 2002). Sequences of events and interactions, rather than specific time scales, are usually emphasized. Decision-makers in the business community and elsewhere have employed scenarios for several decades as an approach to aid decision-making in the face of uncertainty (Chermack et al. 2001; Coates 2000; Davis 1998). Scenarios are generally useful for encouraging systematic planning in situations of uncertainty (van der Heijden 1996) or for revealing a range of dynamic processes and causal chains that lead to alternative outcomes (Rotmans et al. 2000). The intention of scenario planning is to consider a variety of possible futures that include important uncertainties, rather than to focus on the accurate prediction of a single possible future (van der Heijden 1996, Peterson et al. 2003b). Usually, scenario planners start by determining a set of focal questions or issues in conjunction with their primary stakeholders. This is followed by an assessment of the current state of a system, and identification of alternative pathways that the system might take (Peterson et al. 2003b). The focal questions often revolve around key uncertainties or unknowns in the system. The next step is to build storylines by projecting these questions into the future, which can be done either qualitatively or quantitatively. For complex systems, various methods can be used in an iterative process (Alcamo et al. 1998).

Scenarios were first used after World War II as a method for war game analysis (van der Heijden 1996). Their value was quickly recognized by Herman Kahn (Kahn and Weiner 1967) and others who developed the use of scenarios for other strategic planning applications. Scenarios were refined at Royal Dutch/Shell by Pierre Wack in the 1970s and 1980s, and Shell became a leader in the scenario approach to business planning. Today scenario development is used in a variety of different contexts ranging from political decision-making (Kahane 1992, 1998), to business planning (Wack 1985; Schwartz 1996; Davis 1998), to local community management (Wollenberg et al. 2000; Peterson et al. 2003b) and understanding global-scale environmental patterns and processes (Gallopín et al. 1997; Cosgrove and Rijsberman 2000; IPCC 2001; UNEP 2002; van Notten et al. 2003).

For ecosystem assessments, scenarios are seen as a fundamental prerequisite for strategic thinking and planning. In this context, scenarios are used to facilitate strategy formulation and evaluation, develop an understanding of the uncertainty inherent in ecological systems, and test the robustness of response strategies against a set of possible futures. Unlike other decision-making techniques that focus on a single future outlook (such as prediction or forecasting), scenario-building is a cognitive and imaginative decision-making tool. It emphasizes holistic, integrated, and participatory approaches to illuminate the heterogeneity and ambiguity inherent in ecosystem management. Scenarios extend prediction and forecasting methods, providing additional and relevant alternatives to help decision-makers think, talk, plan, and act imaginatively in pursuit of a more sustainable society.

10.1.2 Scenarios in the MA Global Assessment

Scenarios are defined in the MA conceptual framework as plausible alternative futures, each an example of what might happen under a particular set of assumptions (MA 2003). Scenarios were a key tool in the overall MA process that, along with analysis of condition and trends, and responses, provided a comprehensive assessment of ecosystems and human well-being at the global level. The MA conceptual framework envisions scenarios serving as a tool in three ways: (1) to educate local stakeholders on possible future changes in ecosystem services and human well-being; (2) to communicate the overall results of an assessment to a broader audience; and (3) to facilitate decision-making at global and sub-global scales. In the MA global assessment, four global scenarios were developed. (See Appendix 10.1). These differed primarily in terms of the assumptions made about the drivers of change in ecosystem services, and how society reacts to such change.

In the global assessments, model and scenario development consider multiscale processes and heterogeneity by disaggregating the globe into several multi-country regions (Alcamo et al. 1998; Nakicenovic et al. 2000). However, this top-down framework falls far short of embracing smaller scale phenomenon in an interactive, multiscale way.

10.1.3 Scenarios in the MA Sub-global Assessments

The sub-global assessments were strongly encouraged to undertake scenario analyses as part of their assessments. However, sub-global assessments varied greatly in how much emphasis they placed on scenarios in their overall assessment activities, and in the specific goals and focus of the scenario exercises undertaken. (See Table 10.1.) This variation in emphasis led to a wide diversity of outcomes that were not readily comparable.

Scenarios at the sub-global scale may yield results different from those that emerge from disaggregated global analyses for several reasons. First, the set of ecosystem services and the ecosystem changes of interest vary across scales. (See MA 2003, Chapter 5.). Second, the mixture of ecosystem

Table 10.1. Summary of the Scenario Exercises in Selected Sub-global Assessments (Information from specially designed questionnaires, Knowledge Markets in KM1, and KM2)

Sub–Global Assessment	Stated Goals of Scenario Analysis	Main Ecosystem Services and Human Well–being Aspects Considered	Main Methods Used to Develop Scenarios	Spatial Scale	Time Horizon
San Pedro de Atacama	communication with stakeholders	water, biodiversity, minerals, tourism, astronomical observation, agriculture	workshops and expert work	local	
Caribbean Sea	stimulate thinking about the future	fisheries, tourism	workshops and expert work	regional sub-regional	2000–50
Coastal BC		food, biodiversity, fiber and timber, runoff regulation, cultural	workshops and modeling	regional sub-national	–
India Local	assess influences of external forces on local community	food (hunting), firewood, biodiversity	based on "what . . . if" questions for management options	local	–
PNG	change ways of thinking about the future	logging, coastal mining (heavy metals), position of women, birth control	assessment and implications of the past; expert scenarios	national provincial local community	–
Portugal	for users and decision-makers	food, biodiversity, water, soil, recreation	workshops and expert work	national basin local	2050
SAfMA	tool for planning/actions particularly at local scales	water, food, biodiversity, firewood	participatory workshops including community theatre (local); modeling and expert work (basin and regional)	regional basin local	2010–50
Sweden KW and Sweden SU	prepare for surprises, information for planning; obtain stakeholder input	KW: flood buffer, wetland, security from floods SU: green area loss, biodiversity, CO_2 sequestration, recreation, health	expert work	local	2050
Northern Range	stimulate thinking about the future	fresh water, forests, cultural, runoff regulation, and biodiversity	focus groups for developing storylines	national sub-national	2000–2025
Tropical Forest Margins	analyze natural resource management options, future planning; enhance participation; inform policy-makers	biodiversity, hydrological function, forest cover	expert work (Mae Chaem); participatory scenarios (elsewhere, planning)	local benchmark sites ecoregion national	2020–30
Downstream Mekong	visualize the future, information for policy-makers, input for models	rice, shrimp, timber, firewood, medicinal plants, fresh water, security, social relation, freedom of choice		local	
Western China	information for the government, input for models	urbanization, deforestation, water	quantitative modeling	regional local	2010–20
Sinai	for local communication	water (quality/quantity)	workshops—qualitative	local	2010–20
Bajo Chirripó	get in touch with user needs	culture, forest, biodiversity, inland water	workshops—qualitative	local	<2010/2020
Eastern Himalayas	improve response options; inform policy-makers	forest, food, energy, water, biodiversity, land use, loss of life, food security	workshops—qualitative and quantitative	sub-national local	2010–15
São Paulo	envision the future; change bad situations	water, biodiversity, cultural service, soil, livelihood, social conflict	assessment and implication of the pilot expert scenario	local river basin	

(continues)

Table 10.1. continued

Sub–Global Assessment	Stated Goals of Scenario Analysis	Main Ecosystem Services and Human Well–being Aspects Considered	Main Methods Used to Develop Scenarios	Spatial Scale	Time Horizon
India Urban	share information with partners	food, water, fuel, fiber, western culture	individual consultations; literature review	local national	1950–2050
Wisconsin	Improve ecological management	Native American walleye spear fishery, tourism and sport fishing, maintenance of the "Northwoods" landscape, habitats to increase resilience of fish population, nutrient cycling (reducing impact of runoff)	initial expert assessment and scenario development; participatory scenarios workshop; scenarios redrafted by experts	local	2028
Benchmark Example					
Goulburn Broken Catchment, Australia (CSIRO)	show broad range of possible management options	water, crop production, livestock, tourism	stakeholders involved in workshops organized as expert witness jury; modeling	local	

types varies greatly within and among larger regions of the world, and it is far from certain that their resilience to human perturbations and natural disturbances is similar across these regions. Third, the types of human perturbations vary widely within and across regions with, for example, the level of industrialization of production activities. Finally, interacting drivers, institutional responses, and environmental challenges are themselves heterogeneous at the sub-global scale and typically operate on shorter time frames.

The rationale for undertaking scenarios in sub-global assessments varied considerably, often depending on the nature of stakeholder involvement. A number of sub-global assessments directly engaged local decision-makers (for example, Caribbean Sea and India Urban), and scenarios therefore played a role in local decision-making. Another set of sub-global assessments focused on local communities and thus lent themselves to educational and communication purposes (for example, San Pedro de Atacama and Sinai, Egypt); their primary purpose was to start a process of stakeholder involvement in ecosystem management processes. A third purpose of developing scenarios was to use them as input into spatially explicit models (for example, Western China and Laguna Lake Basin, Philippines).

It is important to note that while the teams conducting sub-global assessments were provided with some methodological guidelines for developing scenarios, they were encouraged to develop their own methods where necessary. Consequently, the use of different methods, combined with the focus on specific groups or issues, resulted in the development of a wide variety of scenario types.

10.1.4 Assessing Work in Progress

At the time of writing (January 2005), many sub-global assessments had yet to complete their assessment work. Moreover, scenario analysis is normally one of the final steps in an assessment, as information on drivers, uncertainties, key ecosystem services, and current trends must be available before scenario development can start. This is particularly true for the quantification of scenario results by linking storylines and models (discussed below). Therefore, this chapter often reports on plans and intentions rather than on final conclusions of the scenario exercises. Also, sub-global assessments that had completed their scenario activities usually indicated that theirs were iterative processes. Consequently, the chapter provides a snapshot in time of what is usually a much longer analytical process.

To carry out these analyses, the authors were dependent on a combination of written background documents and responses to queries provided by individual sub-global assessments, direct discussions with those involved in specific assessments, and the two Knowledge Markets (described in Chapter 2, Box 2.1). Among the authors of this chapter were representatives of 10 sub-global assessments. An example from case studies in the Goulburn Broken Catchment assessment in Australia (CSIRO Sustainable Ecosystems 2003) was used as a benchmark reference in this chapter. Though not part of the MA, this assessment is complete and was undertaken in a manner consistent with the MA conceptual framework.

10.1.5 Analytical Framework and Organization of Chapter

To help with the analysis in this chapter, an initial set of questions (Figure 10.1, left column) was developed and sent to all sub-global assessments. The list of questions was refined and additional questions were added in the course of several iterations, with inputs from the sub-global assessments. The right column in Figure 10.1 shows a partial, illustrative list of responses from the sub-global assessments to those questions, highlighting that scenarios were developed for varying purposes, that diverse approaches were used to address the technical challenges of dealing with quantification and scale, and that practical constraints of time, budget, and skills were often faced.

The rest of this chapter analyzes the sub-global assessment scenario experiences based on responses to the ques-

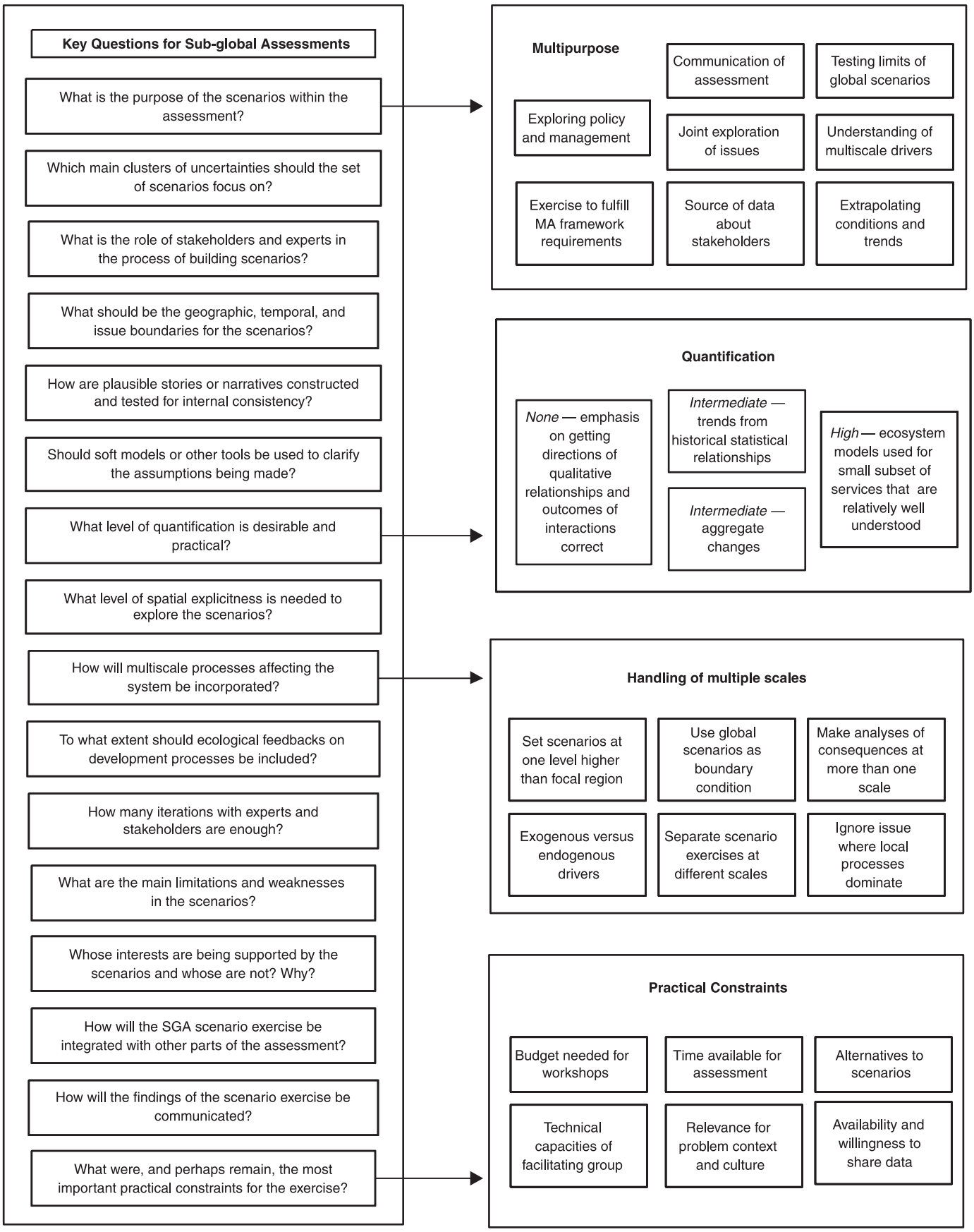


Figure 10.1. Key Questions Asked about the Design and Implementation of Scenario Exercises in Sub-global Assessments and Selected Answers to Four of These Questions

tions along the following dimensions: key uncertainties; methods used to develop storylines; how ecological considerations were incorporated into the scenarios; relationship with the global scenarios exercise; participation in the scenario development process; communication of scenario process and findings; and insights from a comparison of scenario results across assessments. The chapter concludes with a summary of lessons drawn from the experiences of the sub-global assessments, which may be of particular value for future assessments.

10.2 Handling Uncertainties

Scenarios are a useful method for improving decision-making and stakeholder involvement in situations of high uncertainty. When the world is highly predictable, simpler decision-making techniques, such as prediction, forecasting, and other single-future outlooks may be useful (Peterson et al. 2003b). However, such simplicity is rare in ecosystem management. Instead, managers often find themselves confronted with complex situations and a high probability of surprise.

In describing uncertainty, clarity is essential since ''an uncertain estimate'' can mean different things to different people, ranging from an estimate just short of complete certainty to speculation (MA 2003, Chapter 7, Analytical Approaches). Uncertainty can be the result of:

- lack of information or a disagreement about what is known or knowable;
- ignorance or the possibility of surprise, both of which derive from the impossibility of prediction in social-ecological systems;
- linguistic imprecision, statistical variation, measurement error, variability, approximation, or subjective judgments.

Uncertainty can be further compounded by long time lags among driving forces, changes in ecosystem services, changes in human well-being, and responses. For ecosystem management, uncertainties may be unknowns related to the ecological system, such as how vulnerable a system is to disturbance; the social system, such as the strength of the economy over the next 50 years; or the interaction of social and ecological systems, such as how the strength of the economy will affect tourism or logging.

Fundamental uncertainties to be addressed by scenarios relate to key drivers of ecosystem change, and responses by individuals or groups. While scenarios will not resolve uncertainties, they can help stakeholders make better decisions in the face of uncertainty. For example, if the key uncertainty in a particular context is whether the economy will remain strong, decision-makers may choose a policy approach that is likely to be successful whether the economy is strong or weak. The scenario development process may also help decision-makers prioritize the most important uncertainties for further research.

10.2.1 Key Uncertainties Identified in Sub-global Assessments

The main uncertainties that the sub-global assessments attempted to capture in their sets of scenarios varied greatly. While these uncertainties may be classified in many ways, Table 10.2 groups them according to whether they are exogenous or endogenous. Exogenous uncertainties are those uncertainties related to drivers that operate primarily from outside the assessment region for which the scenario was developed. Endogenous uncertainties are related to drivers that are controlled primarily within the assessment region. For a small tourist area in Borneo, an endogenous uncertainty might relate to how much forest a community will cut, and an exogenous uncertainty might include how national and global economic activity will affect the rate of tourism to ''exotic'' locations such as Borneo. Clarifying the uncertainties in this way can improve understanding of what exogenous drivers the sub-global assessment stakeholders thought were important (but largely uncontrollable by them) and what endogenous drivers they considered important (and somewhat more controllable by stakeholders in the system).

Many sub-global assessments identified similar exogenous uncertainties, and not surprisingly, many highlighted broad clusters of issues like governance and markets. In the multiscale Southern Africa sub-global assessment, where the scenarios at different scales were developed independently, governance emerged as a key uncertainty at all scales. For some assessments, resource use outside the assessment area was also a key uncertainty.

Interestingly, the sub-global assessments shared several endogenous uncertainties as well. Common endogenous uncertainties included institutional arrangements, wealth distribution and equity, and governance. In the scenarios developed by the Caribbean Sea assessment, the main uncertainty was whether the region would continue to rely on tourism as its main source of income or whether there would be greater future diversification of the economy. The issue of economic diversification in Caribbean Sea was strongly connected to a set of governance issues such as regional cooperation and trade negotiations.

Many other uncertainties were specific to individual sub-global assessments. For example, HIV/AIDS was identified as a key uncertainty only for the Papua New Guinea sub-global assessment. This does not mean that this factor was not important in other sub-global assessments; it simply means that other scenarios did not identify it as critical for the future. Decisions about key uncertainties are based not only on what factors are unknown, but also on which factors seem, at the time of scenario development, to be the most influential but uncertain determinants of the future.

For example, for scenarios in the Northern Highlands Lake District, Wisconsin, key uncertainties included the future impact of the national economy on tourism and immigration to the region, and local institutional arrangements in the future for managing lakes and the ecosystem services those lakes provide. Changes in the national economy will affect how and where people vacation, which may affect tourism. Changes in institutional arrangements will affect the impact of tourism and other activities in the area, but the influence of these arrangements on tourism in future is uncertain given the many other factors related to the economy or the availability of internal resources that would also

Table 10.2. Major Exogenous and Endogenous Uncertainties across the Sub-global Scenarios. Exogenous uncertainties are those that are driven primarily from outside the assessment region for which the scenario was developed. Endogenous uncertainties are those that are controlled primarily within the assessment region.

Sub-global Assessment	Major Uncertainties	
	Exogenous	**Endogenous**
Tropical Forest Margins	international markets for cocoa, oil palm, timber, and other tropical forest products	human behavior
		adoption of new technologies
	global environmental concerns and actions	institutional arrangements
Western China	central government policy	rate of urbanization
		population growth
SAfMA Regional	governance (national and regional)	governance (local)
	equitability of wealth distribution	equitability of wealth distribution
Wisconsin	impact of state and national economies on tourism and immigration to the region	institutional arrangements (for managing lakes and ecosystem services)
		resilience of ecosystems to changes in local use and management
PNG	balance of power between global and Asian economies	population growth
		HIV/AIDS
San Pedro de Atacama	impact of state and national economies on tourism	institutional arrangements (for managing tourism)
		water use (by tourists, mining industry, and agriculture)
Caribbean Sea	ecosystem vulnerability to change and thresholds	governance mechanisms for ensuring equitable distribution of tourism income
	impact of international economy on tourism	
	climate (impacts on tourism, ecosystems)	
Northern Range	climate variability	distribution of wealth
	ecosystem vulnerability to change and thresholds	long-term economic prosperity
		policy responsiveness
Sweden KW	upstream water use	institutional arrangements (bridging organizations)
India Urban	national governance	rate of adoption of new technology
	empowerment of local communities	rate of urbanization
Portugal	societal attitudes toward the environment (proactive vs. reactive)	societal attitudes toward the environment (proactive vs. reactive)
	national agricultural practices and policies	national agricultural practices
	global connectedness (which also influences these practices and policies)	
Sinai	regional governance	awareness of environmental issues
		demand for ecosystem services
		local water pollution
Laguna Lake Basin	governance	population
	international politics	agricultural intensification
	international markets	industrialization
India Local	markets	institutional arrangements
	legal system (especially with regard to criminalized nomadic tribes)	

influence the amount of tourism in the area. If the Northern Highlands Lake District were to be one of the least developed areas in the American Midwest in 25 years, it may be more highly treasured and visited (and possibly then become more developed).

10.2.2 Describing Key Uncertainties after Identification

Having identified their key uncertainties, some sub-global assessment teams chose to explain their scenarios by using perpendicular axes to describe two major uncertainties, and then locating the scenarios along those axes. For example, the three Wisconsin scenarios can be arranged, post-hoc, along two axes, one from ecological crisis through to gradual ecological change, and the second from local growth to externally driven growth from retirement settlers and tourism. (See Figure 10.2.) The scenarios of the Tropical Forest Margins–Mae Chaem assessment can also be described along axes. In fact, most sets of scenarios could be described along multiple axes of uncertainty and the sub-global assessment teams could choose to explain the scenarios using axes most appropriate to the situation in which each set of scenarios were described.

It is important to note that many sub-global assessments found that the use of axes, while useful post-hoc to explain and describe the scenarios, tended to limit creativity when used as a scenario development tool. In particular, Caribbean Sea participants explained that thinking about the uncertainties in terms of clusters was more useful and allowed them to consider relationships among uncertainties. There is always a wide range of possible scenarios that can be developed, and choosing only two axes tends to narrow this range of possibilities. Therefore, at least at the early stages of scenario development, it may be more productive to embrace the widest range of possible uncertainties and avoid the use of axes.

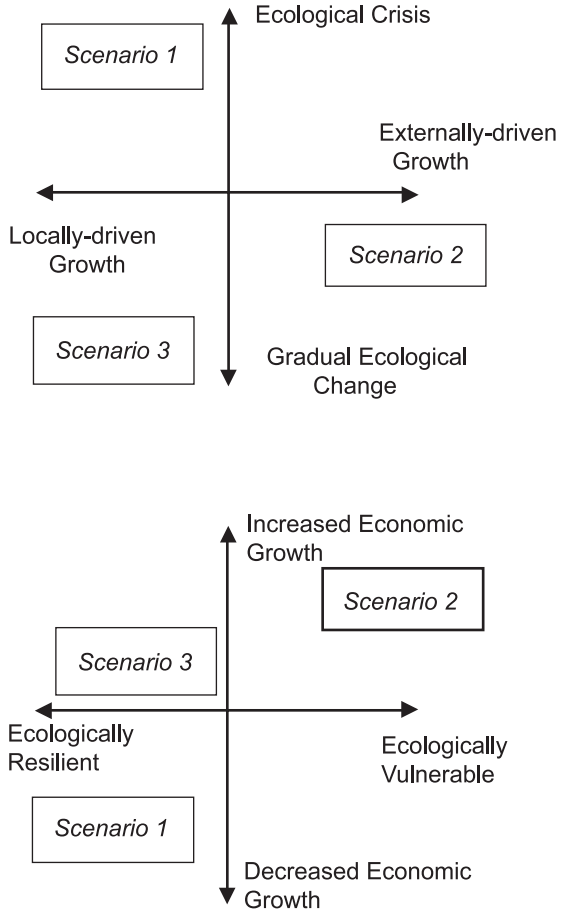


Figure 10.2. Two Sets of Uncertainty Axes That Could Be Used to Describe the Northern Highland Lake District, Wisconsin, Scenarios

10.2.3 Relationships of Uncertainty to Ecosystem Services and Human Well-being

In general, sub-global assessments selected uncertainties by focusing attention on socioeconomic drivers, with much less attention on how these uncertainties might cascade through impacts on ecosystem functions, services, and human well-being. Conceptually, the cascade could lead to either amplified or reduced uncertainties about human well-being. Figure 10.3 illustrates how this could potentially happen. In many sub-global assessments, surprises and shocks to the system and the impact on ecosystem services and human well-being are included in the scenarios. Yet the human responses to these changes are, by and large, not included, although these indirect effects could either dampen or amplify uncertainties.

If resilience is high and there are many redundancies in the system, uncertainties may affect ecosystem function without having much impact on the flow of ecosystem services. On the other hand, if there are few redundancies, small changes to ecosystem function may have a large impact on the flow of services. Management, technology, and other social factors may affect the relationship between changes in ecosystem services and human well-being. If people can use technology to substitute one service for another (for example, hunting or eco-tourism instead of timber products from a forest) or to substitute the provision of a service in the future for provision now (for example, organic farming to preserve the environment instead of conventional farming), it may be possible to adjust to a decline in ecosystem services. However, if these devices are lacking, small changes in ecosystem services may have a large impact on human well-being.

In developing the Wisconsin scenarios, it was recognized that tourists bring income to the area, but also place high demands on ecosystem services. The amount and type of tourism in the future—including whether it will involve motorized water vehicles, require the development of infrastructure, or value quiet natural areas—are examples of the kind of uncertainties that will largely determine the use of ecosystem services and affect the ecosystems' ability to provide those services. In some of the Wisconsin scenarios, increased tourism leads to higher demands on local ecosystems for nutrient cycling, sewage management, and pollution dilution. At the same time, some aspects of human well-being are improved by increased flow of money into the regional economy. Scenario development in the Northern High-

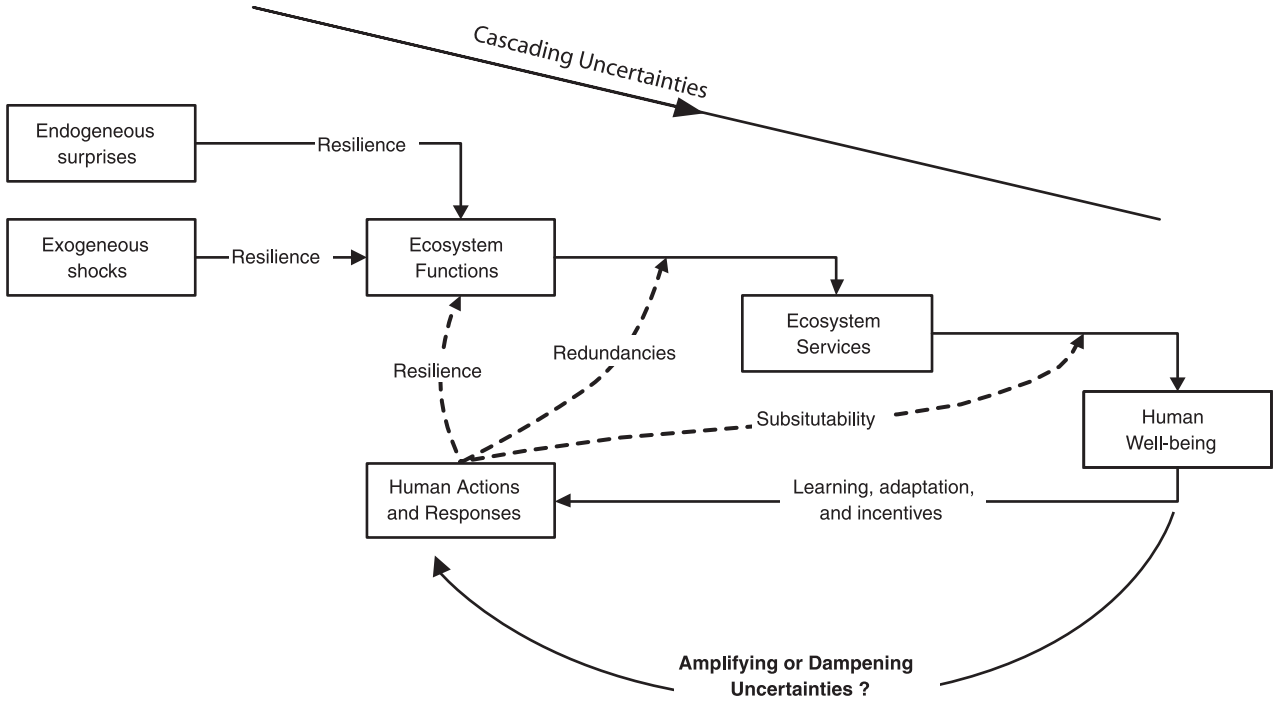


Figure 10.3. Cascading Uncertainties in Social-ecological Systems That Might Be Captured in Scenarios

lands Lake District was useful in thinking about trade-offs such as these and encouraging stakeholder discussion about important future decisions related to managing tourism and ecosystem services.

10.3 Telling Plausible Stories

10.3.1 Diversity of Approaches

A detailed methodology of how to develop scenarios was presented to all sub-global assessments and discussed with representatives of the global MA Scenarios Working Group during a scenario training workshop. (See Table 10.3, and Bennett and Zurek 2004.) Although the ''scenario cookbook'' provided a detailed guide, sub-global assessments were encouraged to adapt the methods to their local circumstances. Unfortunately, not all sub-global assessments were completely clear on what type of scenarios should be developed and this, combined with specific local interests and limited financial resources, led to a wide variety of scenario products that, more often than not, were less elaborate than initially envisioned.

Step-by-step approaches to developing scenarios were documented by the SAfMA assessments and by Caribbean Sea. SAfMA Regional identified governance as the major uncertainty, leading to bifurcation in the storylines for the region over the next three decades. The two resulting scenarios were fleshed out by filling in the MA conceptual framework diagram as a causal diagram. These key bifurcations were translated from the regional scale to the Gariep Basin scale to local studies in a ''cascade'' of progressively refined and locally relevant scenarios (Biggs et al. 2004). The first scenario, named ''African Patchwork,'' relied on projecting current trends (that is, a business-as-usual scenario). The second scenario, ''African Partnership,'' presented a vision of the future based on the strong political support for the New Partnership for Africa's Development. (See Figure 10.4).

Many countries have similar politically endorsed foresighting initiatives, which usually use either *forecasting* (Wollenberg et al. 2000; Rotmans et al. 2000) or *backcasting* (Dreborg 1996; Robinson 1982; Robinson 2003) scenario development approaches to develop a desirable vision of the future based on expected or desired policy directions. One example of a forecasting scenario is the Stockholm Urban assessment, in which a newly developed governmental program for protected areas was evaluated in terms of how it will affect key organizations (for example, NGOs or political bodies) and local stakeholders active in the management of urban green areas. In the case of the Caribbean Sea assessment, both regional and global experts were involved in scenario development. (See Box 10.1 for a summary of the Caribbean Sea scenario development approach.)

10.3.2 Frameworks Used to Develop Storylines

In developing scenarios at the sub-global level, assessments made use of different frameworks to structure their work. Some assessments, such as the Eastern Himalayas, started off by trying to map their local situation directly to one of the MA global scenario archetypes. Other assessments used diagrams with perpendicular crossed axes representing major direct and indirect drivers. The four resulting quadrants then represented the major storyline permutations (examples include Portugal, Sweden SU, and Caribbean Sea). Anticipated changes in drivers were then assessed qualitatively, and storylines developed.

Table 10.3. Steps in the Scenario Development Process

When	Step	Who
Before first workshop	Decide on purpose of scenario and stakeholder involvement	Core team in consultation with main stakeholder groups
At first workshop	Icebreaker: Getting people to think about the long-term future	Stakeholder group with core team facilitation
	Introduce the concept of scenarios	Core team
	Back casting exercise[a]	Stakeholder group with core team facilitation
	Identify main areas of uncertainty[a]	Stakeholder group with core team facilitation
	Develop focal questions to be addressed by scenarios[a]	Stakeholder group with core team facilitation
	Identify main drivers of change[a]	Stakeholder group with core team facilitation
	Develop first set of storylines	Stakeholder group with core team facilitation
	Decide on modeling capacity	Stakeholder group and core team
Between workshops	Prepare documentation material of first workshop	Core team
	Model runs	Modeling teams
At the second workshop	Critically assess storylines and incorporate model results[a]	Stakeholder group with core team facilitation
	Identify important surprises[a]	Stakeholder group with core team facilitation
	Identify implications of scenarios for the main stakeholder groups in the area	Stakeholder group with core team facilitation
	Decide on final storylines	Stakeholder group with core team facilitation
	Evaluate the implications of each scenario for addressing identified uncertainties	
Optional	Wider stakeholder feedback session and scenario iterations	Core team facilitation
After workshop	Final write up of scenario storylines and their implications	Core team
	Dissemination of scenarios write-up	Core team

[a] The sequencing of these steps can vary.

10.3.2.1 Portugal

In the first phase of the national scale Portugal assessment, one of the two major axes of change was related to society's attitudes toward environmental change—reactive versus proactive. The second axis related to agricultural practices in Portugal, particularly the effects of agricultural policies on those practices. In these independently created scenarios, the societal attitudes axis was shared with the global MA scenarios. This convergence between global and sub-global scenarios meant that some of the quantitative modeling already done in the global scenarios could be ground-truthed in Portugal. It also provided the opportunity to scale down the global scenarios, where in the second phase of the assessment, the global scenarios were used to provide boundary conditions for the national scenarios in Portugal. The local assessment of Sistelo in Portugal developed scenarios independently, the results of which were later integrated into the national scenarios (Pereira et al. in review).

10.3.2.2 Tropical Forest Margins–Mae Chaem, Thailand

The Tropical Forest Margins–Mae Chaem scenarios also started with two contrasting perpendicular axes. The first captured the character of linkages to outside regions (localized versus globalized), and the second captured the sectoral composition of economic development (agricultural versus diversified). Taken together these two axes were seen as determining a third composite axis of ''connectivity'' (or cluster of processes), which appeared to capture an essential cluster of features in each of the quadrants that were subsequently developed into each of the contrasting scenarios.

10.3.2.3 Southern Africa Assessments

The SAfMA nested assessments adopted an experimental approach to multiscale scenario development. Each SAfMA component assessment selected methods designed to answer the questions relevant at its particular scale, while also attempting to retain multiscale comparability. The local scale data were largely collected using participatory methods, while the basin and regional scale studies primarily made use of published studies, national and international databases, and modeling approaches.

At the basin scale, existing scenarios previously produced for the region were first explored. Subsequently, the feasibility of adapting elements of the MA global scenarios was investigated. After reviewing existing scenarios, the choice was made to develop a set of scenarios with input from stakeholders and the other Southern Africa component as-

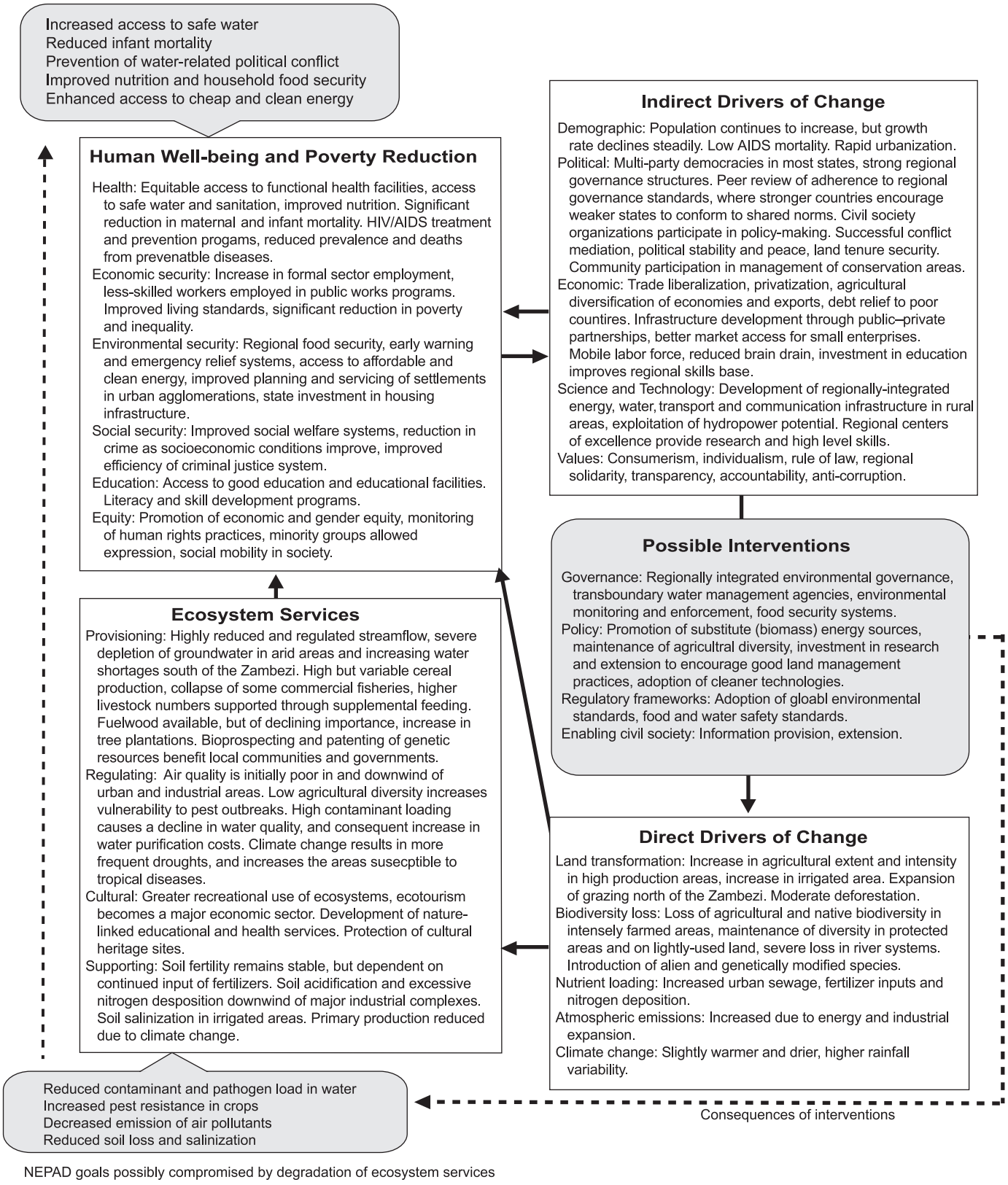


Figure 10.4. The Southern Africa Regional Assessment Scenario Development Approach. The Southern Africa Regional assessment made use of the MA conceptual framework to synthesize several existing regional scenarios. The African Partnership scenario was based on an action plan called the New Partnership for Africa's Development, a politically endorsed initiative for the economic and social development of the continent. By mapping the main aspects of the action plan into the framework, it was possible to identify targets that may be comprised by the degradation of ecosystem services.

BOX 10.1

Developing Storylines: The Caribbean Sea Approach

The Caribbean Sea assessment pursued a two-part approach to developing scenarios, first encouraging stakeholder involvement, and then refining and testing scenarios.

Part I: Stakeholder involvement (conducted separately in small breakout groups)

1. *Assess current knowledge and the current state of the system*
   - List key historical eras, key actors, external forces affecting the region, and ecosystem services.
2. *Identify a focal issue or issues*
   - List hopes and fears for the future to determine focal questions that might drive scenario development.
3. *Identify alternative trajectories and branch points*
   - Identify key sources and threats to the resilience of the region (the ability to adapt to future surprises). Focal questions for Caribbean marine ecosystems were developed based on: What is the biggest concern for the region in the future? What are the factors that can make this region better able to cope with whatever the future brings?
4. *Build scenarios*
   - Ask breakout groups to come up with a set of storylines, based on the focal questions and considering the major historical eras and vulnerabilities of the region. Groups were asked to do this in 1 hour to create a sense of urgency. Each group was then asked to present their set of scenarios in a plenary session.

Part II: Refine and test the scenarios (conducted with a single, small focus group)

5. *Assess the scenarios*
   - Are there certain themes emerging? Can we come up with a set of four or so that seem to make sense together? What are the critical contrasts among the scenarios? What are the recurring themes? Are the trends/events plausible? What trends/events are useful for illustrating key themes or concepts?

   Does the set of scenarios address the focal questions?
6. *Shocks and surprises*
   - Come up with a list of shocks and surprises that might happen and ask how the world would respond under each of the scenarios.
7. *Use this analysis to refine a final set of scenarios.*

sessments at the regional and local scale. At the local scale, future scenarios for three local sites within the Gariep Basin were constructed during a workshop for project team members using the following steps:

- Static drivers of change were identified. These are known drivers and trends that will not change within the time horizon considered but will have an influence on the future that unfolds.
- Assumptions were identified and listed, especially those relating to dynamic variables that have the potential to change during the time horizon considered, but were not expected to change.
- The key uncertainties were identified. These are dynamic variables that were expected to change during the forecast period and to influence the outcome of the scenarios. Changes in the influence of these drivers, or possible options around key uncertainties, were then elaborated for each driver.
- Drivers of change were ranked from potentially the most influential to the least.
- Correlations between drivers were identified, and where detected, the least influential driver was omitted.
- A suite of proto-scenarios was then developed from combinations of different pathways for each of the most influential drivers.
- Each resultant scenario was then assessed in terms of its feasibility and probability. Those scenarios deemed unfeasible or improbable were then omitted.

From within the final suite of scenarios, a subset was selected, so that each scenario represented a cluster at different stages along the primary iteration. These were then fleshed out in narrative form with respect to the state of issues/descriptors of interest under such combinations of drivers of change.

In summary, most sub-global assessments used some variant of the MA methodology to develop largely qualitative stories based on major drivers of change. There was little evidence of the use of causal diagrams, but the San Pedro de Atacama and SAfMA Regional assessments demonstrated a relatively simple approach to filling in the MA conceptual framework to accomplish the same end.

10.3.3 Systems Models, Quantification, and Spatial Explicitness

The most common approach among sub-global assessments was to opt for *qualitative scenarios* that relied either on unstructured narratives (for example, India Urban and Eastern Himalayas) or more structured sequences of events (for example, Coastal BC, Sinai, and San Pedro de Atacama). This is a logical first step in scenario development and the most effective way to engage a wide variety of stakeholders. Many sub-global assessments noted the desire to quantify storylines, yet in many cases, time constraints and the lack of a calibrated and validated quantitative model for the assessment area limited the possibilities for linking to models. Quantitative scenarios based on computable model-based exercises (such as Western China and SAfMA Regional) were therefore less common. However, the rarity of quantitative analysis could well be a consequence of the relatively short period of sub-global assessment work considered in this chapter. In the future, many sub-global assessments might engage in quantitative analyses of the various scenarios.

Structural or soft models and event sequence diagrams were used in the Tropical Forest Margins–Mae Chaem scenarios to help clarify the logical assumptions behind each of the stories. (See Figure 10.5.) These were prepared before the text was written, and then partly revised and adjusted as the storylines became richer and more specific. Within the India Urban assessment, a qualitative, structural diagram with feedbacks based in implicit data and relationships was used. Several case studies in the Goulburn Broken Catchment assessment in Australia (CSIRO Sustainable Ecosys-

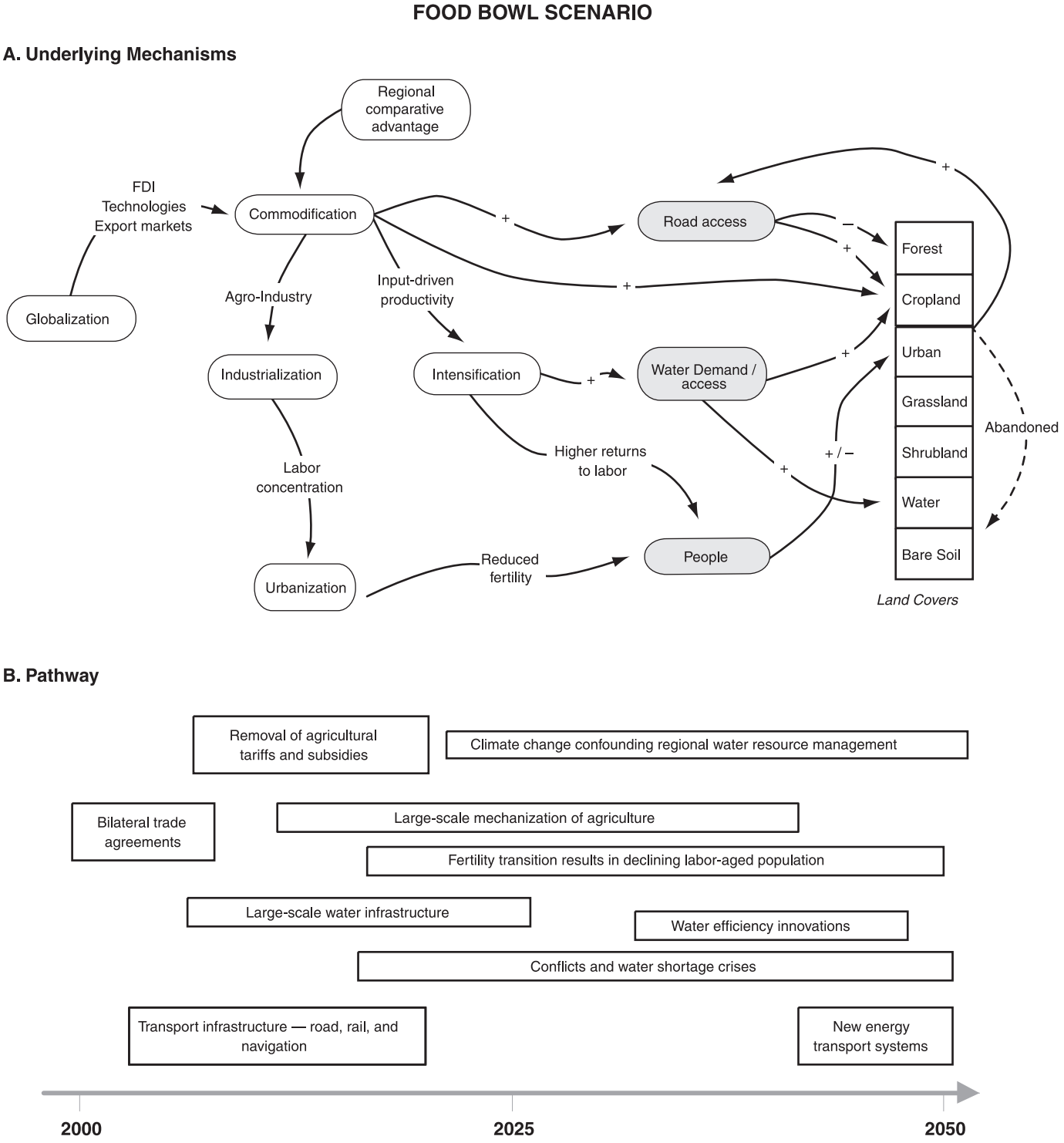


Figure 10.5. The Use of Soft-models as an Intermediate Step in the Forest and Agroecosystem Trade-offs in the Humid Tropics (Tropical Forest Margins) Scenario Exercise

tems 2003) made use of explicit system dynamics models quantifying ecological processes and, in some cases, financial returns.

Some scenario exercises produced high-resolution maps of land use and land cover. In Western China, scenarios were developed specifically to link to a Geographic Information System-based model, and scenarios were therefore quantitative rather than qualitative. Several other sub-global assessment groups indicated that they plan to use spatially explicit models at a later stage (Laguna Lake Basin, Downstream Mekong) using rather simple but easily applicable models like CLUE-S (Verburg et al. 2002). In SAfMA Regional, extensive use was made of various models (Biggs et al. 2004) to assess the effects of different scenarios on biodiversity. Figure 10.6 shows the results of runs of the IMAGE model (Alcamo et al. 1998) for two regional sce-

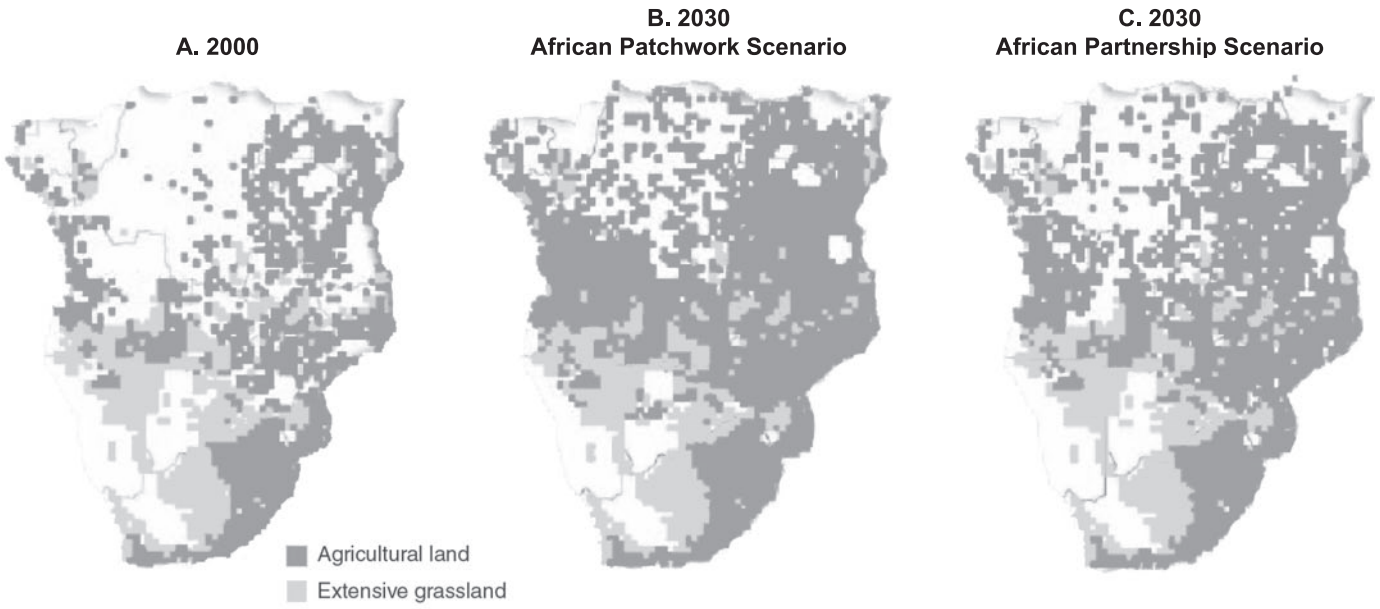


Figure 10.6. Example of Spatially Explicit Scenario Outputs in the Southern Africa Regional Assessment. Projections of land cover change using the IMAGE model for the (b) African Patchwork and (c) the African Partnership scenarios. (Scholes and Biggs 2004)

narios, African Patchwork and African Partnership. In this application, a downscaled version of an existing global model was used, showing one way in which scenario quantification can be done.

As a rule, scenario development exercises that used quantification did so for only a restricted part of the overall issues they set out to explore and assess. This is a sensible approach since frequently the objective of scenario development is to allow exploration of uncertainties, surprises, and thresholds, not all of which are easy to model quantitatively.

10.4 Incorporating Ecology into Scenarios

The use of scenarios in the MA was intended to differ from earlier exercises in that the MA explicitly set out to integrate ecology into the scenarios design (Bennett et al. 2003). Ecosystems were not to be treated solely as passive recipients of the impacts of changes in socioeconomic systems, but also as having a role in jointly determining social futures. Changes in the flow of ecosystem services are seen as potentially altering future development pathways. This view of how integrated social-ecological systems unfold over time is much more co-evolutionary than in scenario exercises where the goal is only to assess environmental changes.

10.4.1 Ecological Detail in Scenarios

Despite the MA's focus on ecology, the ecological detail in most sub-global assessment scenarios was relatively weak. While the impact of external and internal shocks to ecosystems and the consequences for ecosystem services and human well-being were considered by the sub-global assessments, the scenarios developed did not explicitly include ecological feedbacks (see also Figure 10.3). Usually, the focus was on socioeconomic factors and the consequences of these for variables such as land use change, biodiversity, or food production. The examples below draw on two completed assessments that did attempt to include ecological feedbacks.

Several case studies in the Goulburn Broken Catchment assessment (CSIRO Sustainable Ecosystems 2003) made use of explicit system dynamics models to explore alternative land management scenarios. For example, in the Goulburn River Floodplain, Australia, case study, dynamic models of biophysical processes and a land management model were developed to explore alternative land management strategies. In this landscape, the alternative land uses were combinations of cropping, grazing, and conservation. The scenarios identified strategies to maximize financial returns and conservation value, meet targets for protection of different vegetation types, and create mixed land uses to achieve multiple goals. Through a model interface, this approach helped users to explore trade-offs and spatial interactions among ecosystem services.

The Northern Highlands Lake District of Wisconsin has been a field laboratory for ecological research for several decades, and a site for long-term ecological research funded by the U.S. National Science Foundation since 1982. The assessment analysis benefited from a tremendous baseline of ecological (as well as demographic and economic) information. Thus the scenario exercise, focusing on lake ecosystems, was able to bring substantial ecological explicitness into the analysis. For example, narratives on how different actors would use various ecosystem services, what may drive changes in these services (for example, biological invasions, climate, human migration), and the linkages between these, were constructed.

The India Urban assessment included the negative feedback of the constant drain of soil nutrients, water, and carbon to the sea and atmosphere due to urbanization and

declining annual productivity, as well as overall scarcity of food, water, and fuel services. In SAfMA, modeling exercises were used that included feedbacks, while in the Caribbean Sea assessment, the negative feedback on the economy of the entire region that emerges from ecosystem (coral reef) destruction by overfishing and tourism was explored.

10.4.2 Ecological Interactions and Surprises

Several sub-global assessments considered the possibility of ecological surprises. For example, the India Urban assessment addressed potential surprises such as global increases in flooding and the collapse of transport systems due to unanticipated abrupt climatic change; scenarios discussed how cities affected by such calamities might sink, starve, and perish, while some upland subsistence farmer communities could survive.

The Wisconsin assessment has the best example of using scenarios to consider the implications of ecological surprises (Carpenter et al. 2003; Peterson et al. 2003a). In the ''Walleye Commons'' scenario, conflict over resource use interacts with a series of unexpected environmental changes, including climate shifts that affect winter tourism, fishery collapses, and zoonotic diseases. These unexpected events provoke conflicts as different groups blame each other for the resulting losses. The net effect of the social and ecological breakdowns is an exodus of many people from the region.

10.5 Dealing with Scale

The MA design process placed strong emphasis on gaining better understandings of interactions between human activities and ecosystem services at multiple scales. In the light of Chapter 4 of this volume, which examines the scale-related issues in conducting an assessment, and of Chapter 5 of the MA conceptual framework (MA 2003), the discussion in this chapter addresses the specific challenges in developing multiscale scenarios.

10.5.1 Multi- and Cross-scale Processes in Scenarios

Multiscale processes were taken into account in *all* sub-global assessment scenarios, but often this was limited to incorporating ''exogenous'' drivers in the construction of scenarios and making general comparisons with global scenario exercises. Such a limited approach makes sense where cross-scale interactions are primarily top-down or relatively unimportant in comparison with the processes that take place at the scale of primary interest of an assessment. Above all, this keeps the analysis simpler—one of the main reasons given by several sub-global assessments for declining to invest more resources for including multiscale considerations in their scenarios. (See Table 10.4.)

Table 10.4. Reasons Given by the Sub-global Assessments for Excluding or Including Multiscale Considerations in their Scenario Exercises: Selected Examples

Reasons for Excluding Multiscale Considerations	Reasons for Including Multiscale Considerations
The importance of the local issue exceeds any possible global development *Example: Sweden KW.* Recent flooding events have put the question of protection against flood water high on the agenda. The main issue is whether dikes should be raised or new wetlands should be created. Global issues like climate change are important, but the issue is clear and mostly local.	**Regional scenarios that bridge the local and the global already exist** *Example: SAfMA.* Scenarios in this assessment built on a number of sub-Saharan scenarios that already existed.
National government is dominant in the organization of national resources to implement sustainability goals *Example: Western China.* China's economy is no longer centrally planned, and local government and people have significant roles in taking decisions on local affairs. At the same time, China is affected by global change and the international market economy, for example through the accession of China to the WTO. Nevertheless, because China is very large and has many nationalities, the national government is dominant in the organization of national resources and the Western China sub-global assessment was structured accordingly.	**Links between regional and global levels are strong and evident** *Examples: Caribbean Sea.* This area of the Caribbean Sea includes parts of around 30 countries at the regional level, which facilitates the link to global scenarios. Additionally, many issues are the same at both regional and global levels. *Portugal.* Scenarios were first developed independently at the national level, and proved so similar to the global scenarios that the global scenarios were taken and adapted to Portugal instead.
Information at the regional level is inaccessible and an analysis is impossible for security reasons *Example: Sinai.* The Sinai desert is a strategically important region; information at any level above the local is scarce and often not accessible.	**The link between the local and the global is strong.** *Example: Sweden SU.* In general, less isolated local areas have more connections with the regional and global levels and, consequently, translation of issues across scales is easier.
It is difficult to link the local level to global scenarios *Example: Bajo Chirripó.* This assessment focused on the needs and concerns of the indigenous people in the area. The user needs here are so different that linking to global level scenarios was difficult.	

Some sub-global assessments used the global scenarios to set boundary conditions for the scenarios developed in their assessments. The SAfMA local assessments used basin-level scenarios to set their boundary conditions; and the basin-level scenarios in turn considered regional scenarios for the same purpose. In the Caribbean Sea assessment, scenarios were primarily targeted at the regional level, and the global scenarios were explicitly used as boundary conditions.

To incorporate more complexity into their scenarios, however, a few assessments—notably SAfMA and Portugal—used more sophisticated multiscale scenario methodologies. Although these two assessments were exceptions

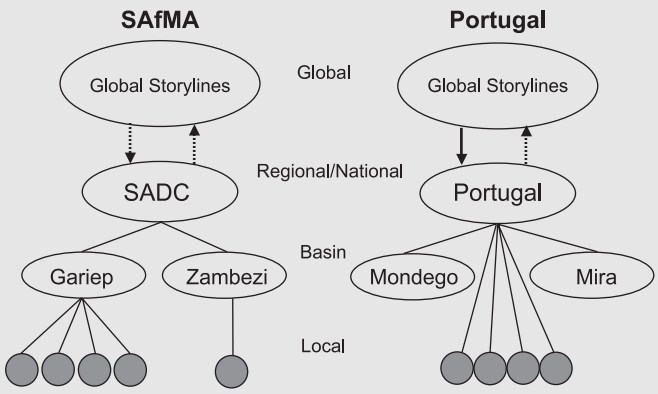
rather than the rule, they demonstrate the potential of employing multiscale methodologies by developing internally consistent stories at more than one scale. In the Southern Africa set of assessments, there were three levels of assessment, each involving at least some scenario activities. Though linked, these separate scenario exercises primarily addressed the particular needs and goals of each of the component assessments. The Portugal assessment also worked at multiple scales, but cases at the local scale were not completely nested in the larger-scale scenarios. (See Box 10.2.)

The Tropical Forest Margins–Mae Chaem scenarios were planned as one of six sets of scenarios to be developed for the benchmark sites of the Alternatives to Slash-and-Burn consortium in six countries worldwide (Brazil, Peru, Cameroon, Indonesia, Thailand and the Philippines). At the same time, these scenarios were also linked with two additional new exercises in northern Thailand and the Mekong River Basin (across the five countries of southwest China, Laos, Thailand, Cambodia, and Viet Nam). The geographical scope of the scenarios in each case was set at a scale broader than the focus area for assessment and simulation of landscape trajectories. This was considered extremely important in these assessments because of the major assumptions on historical, cultural, trade, investment, and information links, and the structure of the regional economy. At the time of writing of this report, scenarios for a rural area (the Mae Chaem watershed) have been completed, and those for an urbanizing area (greater Chiang Mai) were underway.

Explicit nesting of scenarios is advantageous, but it also introduces increased complexity in scenario work. Nesting allows for some preliminary consideration of the plausibility of particular scenarios unfolding at one scale in the face of changes at another. When these mixtures are cross-tabulated, many ''discordant'' combinations can be eliminated as unstable and unlikely to persist. For example, it is hard for northern Thailand to pursue a strong, locally oriented development trajectory while the wider region unfolds in a

BOX 10.2

Nested, Multiscale Design: SAfMA and Portugal



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 MA global assessment, but were not linked to the global scenario storylines (dotted lines in the figure).

Scenario development followed the same general design. SAfMA derived two scenarios by synthesizing information from several recent scenario exercises in the region, rather than developing its own scenarios. The classification of existing regional and global scenarios into a limited number of archetypes provided the basis for interaction and comparison with the MA global scenarios working group. The Gariep Basin assessment used four scenario archetypes and explored what it would mean for ecosystem services and human well-being if the conditions of each of the archetypes prevailed in the basin.

The local community assessments within the Gariep Basin focused on identifying the key drivers in the different study areas. The likely permutations of these drivers were considered and led to the development of three scenarios. The local Gorongosa-Marromeu assessment (within the Zambezi Basin) used scenarios in the sense of ''wind-tunnels'' for testing the robustness of policy and management responses in alternate plausible worlds.

The Portugal 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 reporting units included a very small rural community (mountain system), two farms (cultivated systems), and a biological research station (Montado system). National scenarios were first developed independently and in a second phase compared with the global ones.

One of the two axes of the Portugal scenarios was similar to one of the global ones, and congruence between the Portugal and global scenarios could be established. Thus the Portugal assessment decided to adopt the global scenarios as boundary conditions for the national scenarios, and developed storylines accordingly. This also allowed the use of the quantitative modeling work already done in the global scenarios, and provided a test for the scaling down and regional calibration of the global scenarios.

The Portugal assessment plans to develop scenarios for basin and local assessments also using the global scenarios. Nevertheless, the local community assessment of Sistelo developed independent scenarios that were subsequently integrated with the national scenarios.

highly globalized and interconnected manner. Although this approach of examining ''discordance'' among scenarios created at different levels is pragmatic, it still falls short of allowing for dynamic feedback between scenarios at various scales.

10.5.2 Spatial Extent, Heterogeneity, and Resolution

The sub-global assessment scenario exercises varied substantially with regard to spatial extent, boundary setting, and handling of spatial heterogeneity.

The spatial extent at each level was typically defined either by socioeconomic (for example, village, city, nation) or biophysical (for example, watershed) boundaries. For example, even within the various SAfMA component assessments, different criteria were used to set boundaries. SAfMA Regional was defined by a political grouping of countries (the Southern African Development Community); SAfMA Gariep and SAfMA Zambezi were defined by large drainage basins (the Gariep and Zambezi basins, respectively); SAfMA Gorongosa-Marromeu and SAfMA Livelihoods had boundaries that were politically defined.

To understand the implications of spatial heterogeneity, several sub-global assessments used baseline maps of biophysical or basic demographic features to help understand how scenarios unfold differently at different locations. In these cases, the resolution often differs. For example, the simulated landscapes in the Tropical Forest Margins scenarios at the Mekong Region scale were based on 10x10 kilometer gridded input data and processes at this and higher aggregated scales; in contrast, the Tropical Forest Margins–Mae Chaem simulations used a 1x1 kilometer grid as the basis for land use change. The latter landscape may in future be modeled hydrologically on a finer 30x30 meter digital elevation grid.

The issue of spatial resolution and heterogeneity is closely related to decisions about nesting. In practice, developing full scenarios for more than 2 or 3 scales is difficult to envision, but additional detail for some ecosystem services may nevertheless be available through (dis-)aggregation and mapping techniques.

10.5.3 Time Horizons

In general, one human generation was the longest temporal scale considered by stakeholders, and therefore scenarios in the various sub-global assessments usually limited themselves to a 15–25 year time horizon, though a few extended the time period considered to 2050. However, the SAfMA local assessments noted that traditional communities might use much longer time horizons in their planning. Some also included a longer historical time period. For example, the India Urban assessment analyzed the rise and fall of the British Empire over the past centuries. In several assessments, the temporal dimension was not made explicit. ''What if . . . scenarios'' (Coastal BC) and (un)desirable futures (Karnataka village cluster in India Local) are two examples. The aim in these assessments was to reason through the effect of certain policy measures and their ability to deliver desirable futures, rather than to discuss particular time frames. Both these approaches are particularly appealing options when stakeholders are heavily involved in the process; discussions tend to be livelier and results more creative when participants are asked to develop visions for a desirable future or to respond to certain policy measures, without being concerned with questions about exactly when things will happen (Robinson 2003; Kok et al. 2006).

Immediate issues of concern to stakeholders can limit people's perceptions about what is a useful time frame for scenario development. As was stated by the Papua New Guinea assessment in a Knowledge Market session, ''Even at the national level, there is a strange unwillingness on the part of national bureaucrats to think beyond the next five years'' (Colin Filer, personal communication, KM2).

10.5.4 The Linkage between Sub-global and Global Scenarios

Sub-global scenarios often targeted specific user groups and/or addressed specific questions. Therefore, it was not always possible to link the sub-global scenarios to the global scenarios. To harmonize the global and sub-global scenario exercises as much as possible, the following steps were taken:

- Representatives of several sub-global assessments participated in the global scenarios working group.
- Participants of the global scenario team participated at various occasions in meetings of the sub-global assessments, explaining both the preliminary global scenario results and the procedure that was followed in developing the global scenarios.
- At several MA Sub-global Working Group meetings, representatives of the various sub-global assessments were given the opportunity to discuss methodologies with each other. For example, the two Knowledge Markets facilitated the interaction among representatives of most sub-global assessments.

The sub-global assessments had to make practical decisions about how they would make use of the still-evolving global scenarios in their own work. Most groups explicitly opted to focus first on the needs and issues in their sub-global assessments, rather than be overly bound by the directions taken by the global scenarios. This made sense given that sub-global scenarios need to have relevance and explore the options available to decision-makers at sub-global scales.

Nevertheless, exploring commonalities and differences between individual sub-global assessment scenarios and the global scenarios may highlight gaps in logic at either scale or, in some cases, genuine regional differences that are not apparent in more aggregated analyses. These comparisons may also reveal ways in which the global scenarios could be improved to take into account regional differences. Particularly relevant are the sub-global body of information on quantitative, scale-dependent variables such as biodiversity and land degradation. The spatially explicit information gathered by the SAfMA Regional assessment (Biggs et al. 2004) on changes in ecosystem services is a good example.

Different possibilities exist for how scenarios can be nested within each other to create a set of multiscale scenarios. We distinguish five ways to link global and sub-global scenarios:

- The global storylines can be played out at sub-global scales. This would likely be the strongest link, where the global scenarios are downscaled to finer scales, but where the main storylines are similar.
- The global scenarios can be used as boundary conditions for finer scale scenarios, which then develop their own storylines. For example, the trends described for the major driving forces at the global scale can be used for describing the range of variability these drivers exhibit at a regional level.
- The global scenarios can be used to create scenarios about policy and management options being discussed at the sub-global level.
- The underlying assumptions and worldviews played out in the global scenarios can be applied to developing scenarios at sub-global scales.
- Scenarios can be developed independently at global and sub-global levels and can then be compared and mapped against each other afterwards.

These potential methods of linkage were identified in consultation with the sub-global assessments. The fourth and fifth methods of translating worldviews and mapping global and sub-global scenarios onto each other post-hoc were most frequently adopted. It can be expected that with more sub-global assessments developing scenarios, the other methods will be increasingly employed.

Several sub-global assessments (Portugal, PNG, Caribbean Sea, and SAfMA Regional) compared their independently developed scenarios with the four global storylines. The Portugal assessment independently developed scenarios at the national scale, and when compared to the global scenarios, one axis of change was found to be shared in common. Because of this similarity with the global scenarios, the Portugal scenarios were replaced by the four global storylines adapted to Portugal. This replacement also made sense in that it allowed for the quantitative modeling already done in the global scenarios to be applied to the Portugal scenarios work. Furthermore, sub-global use of global scenarios could test methods for scaling down scenarios and provide regional calibration of the global scenarios. The Portugal assessment plans to further downscale the global scenarios to basin and local levels. Sistelo, a local community assessment within the Portugal assessment (Pereira et al. in review), developed independent scenarios that were later integrated into the national scenarios. Most other groups did not find such a close overlap in objectives, key uncertainties, or trends and processes between their scenarios and the MA global scenarios. The PNG assessment noted that the ''MA is itself an activity which belongs to what we call the Globalization scenario'' (Colin Filer, personal communication, KM2).

10.6 Participating in Scenario Development

An important reason for developing scenarios is to construct a more comprehensive analysis of the social-ecological system. Some stakeholders know a tremendous amount about how systems work ecologically as well as socially, and their knowledge is more integrated compared to traditional academic analyses. Most sub-global assessments acknowledged the need for participation but indicated that limited time and budgets put constraints on what could be achieved. However, closer inspection reveals that sub-global assessments differed widely with regard to the reasons for seeking stakeholder participation, who was invited to participate, and the roles they were assigned in the process.

10.6.1 Goals of Participation

Within the context of the MA emphasis on engaging with assessment users, sub-global assessments gave very diverse reasons for seeking stakeholder participation and, after their experiences, revised their perceptions about the value of participation. Some assessments wanted to communicate policy options *to* stakeholders, while others sought to encourage communication among them. For others, the primary interest was to create ''buy in'' to the assessment process. Buy-in refers to the process of first establishing mutual trust among scientists, decision-makers, and other stakeholders, and subsequently establishing a common understanding of the aims of the assessment, the value of participatory processes, and the possible benefits for local stakeholders. For example, the Wisconsin assessment tried to involve indigenous people, which proved difficult due to a history of conflict and lack of trust between the state, non-native local people, and native people. Few assessments employed specific methods to differentiate the perceptions of various local stakeholders on future developments. The focus of the work remained on communication with stakeholders regarding their opinions about the future, without analyzing differences in perceptions among various people or groups.

For simplicity, we synthesized the reasons for seeking stakeholder participation into several main themes. (See Table 10.5). Most of the reasons given were instrumental, that is, aimed at improving the quality of the assessment or at selling its message. However, normative reasons could also have been part of the rationale and some examples of these are listed at the bottom of the table. Leaders of sub-global assessment scenario exercises and stakeholders who actually participated in the exercises probably had different reasons for participating. Of course, the extent to which their various goals were met depended greatly on the methods actually used to engage stakeholders, and which stakeholders actually participated.

10.6.2 Selection of Participants

Unfortunately, most sub-global assessments provided little documentation of the criteria, reasons, and processes by which the participants in scenario work were selected. The sub-global assessments had received detailed guidelines from the MA on the stakeholder selection process (see Bennett and Zurek 2004), emphasizing that stakeholder selection is a crucial step. Stakeholders can strongly influence the

Table 10.5. Reasons for Seeking Participation in Sub-global Assessment Scenario Development Exercises

Instrumental (often expressed)

Persuade and advocate environmental concerns. To raise environmental awareness and increase the ecological knowledge of stakeholders.

Capture an audience. To help achieve buy-in to the assessment process.

Facilitate communication. Discussions around scenarios were used to help explain assessment findings to various stakeholder groups in a flexible form that related easily to their planning and decision-making concerns.

Instrumental (less frequently expressed)

Increase the diversity of perspectives. Scientists have only a small range of experiences and interests. Stakeholder participation helps broaden the perspectives that can be included in the scenarios, making them more realistic and robust.

Improve understanding of social processes. To more accurately capture preferences, values, and possible response behaviors.

Ensure relevance. To ensure scenarios relate to the priorities of managers and decision-makers.

Normative (not usually expressed)

Rights of stakeholders. It should be the right of stakeholders to have their diverse interests represented at the table.

Experts are shortsighted and biased. Experts and facilitators of scenario exercises should not let their biases predetermine the direction and emphasis of scenarios. Participation helps to mitigate such shortsightedness.

outcome of a scenario activity, because they can differ greatly in substantive judgments and/or worldviews.

The SAfMA assessments established a set of advisory committees for governance as well as for types of involvement in the various scenario exercises conducted at different scales. In contrast to the Goulburn Broken Catchment scenario exercise described below, SAfMA found that it was easier to engage stakeholders at the local scale than at the regional scale. Regional decision-makers at the supra-national scale (for example, SADC officials) were particularly difficult to involve.

Sub-global assessments carried out at finer scales (Vilcanota, Bajo Chirripó) placed special emphasis on engaging local and indigenous people, who would experience the effects of scenario outcomes directly. In other sub-global assessments (Sweden SU, Sweden KW, and Western China), the scenarios were very narrowly focused, and therefore assessment teams could target a relatively narrow group of stakeholders for participation. Probably the broadest stakeholder involvement was in SAfMA Livelihoods, SAfMA G-M, and India Local, each of which involved a broad sampling of civil society, including young people in particular.

For various reasons, including budget constraints, the Goulburn Broken Catchment assessment in Australia focused on the participation of key political stakeholders. In this context, representatives from local, state, and commonwealth governments, the Goulburn Broken Catchment Management Authority, community leaders, and a few nongovernmental organizations were targeted. The assessment then made sure that these groups participated in regular workshops, as well as being part of steering and management committees of the assessment (CSIRO Sustainable Ecosystems 2003).

10.6.3 Mechanisms of Participation

Although workshops were the most common tool for defining or refining existing scenarios, a wide range of mechanisms were employed to engage stakeholders in the scenario-building process. Some sub-global assessments that were still in the scenario planning process at the time of writing (for example, São Paulo) intended to employ more innovative facilitation methods to improve engagement of participants, including role-playing games, computer games, and citizens' juries (also the main method used in the Goulburn Broken Catchment study). Most sub-global assessment groups acknowledged that workshops with stakeholders are expensive, and take effort and skill to prepare and implement. The number and size of these activities were clearly constrained by time and financial resources in most sub-global assessments. The Caribbean Sea assessment followed stakeholder workshops with expert group meetings to build multiscale scenarios.

Interview techniques were also employed (India Local, Sinai), as well as a range of other more informal meetings, mostly in the early phases of the assessment. In India Local, researchers were stationed in the villages, thus effectively monitoring and interviewing the stakeholders for longer periods of time.

Within the Wisconsin assessment, questionnaires were distributed and a website was maintained for public discussion and feedback. Individual interviews to discuss the scenarios were conducted with leaders of local government, Native American tribes, and lake associations. People in the region were surveyed randomly to gather their opinions of the scenarios. A computer game for managing the region was developed and tested with small groups of stakeholders; eventually the computer game will be used in workshops to revise the scenarios both qualitatively and quantitatively. The scenarios have been widely covered in the media. Although this project began as a largely expert-driven exercise, it has matured over time into providing more and more avenues for public participation. As a result, the scenarios are likely to be iteratively refined, as acknowledged at the end of the first phase by the authors (Peterson et al. 2003a).

10.6.4 Roles of Participants

Participation in scenario-building activities ranged from passive roles, where stakeholders served simply as an audience, to highly interactive experiences, where participants were called upon to directly shape, design, and validate the scenarios. The ability to have direct input into the creation of scenarios, in addition to scenario validation, represents a more fully participatory approach. Coastal BC, India Local, India Urban, Tropical Forest Margins–Cameroon, Wisconsin, SAfMA Livelihoods, SAfMA G-M, and Portugal, all employed workshops at some stage of the assessment to gather valuable input on scenario design, as well as to review the scenarios.

10.6.5 Problems Encountered in Participation

Although most sub-global assessments lack documented information on stakeholder involvement, the two Knowledge

Markets provided many insights on some of the problems encountered in the scenario-building process. It is difficult to assess the underlying reasons for the problems that were mentioned, but a few insights can be learned from these discussions.

Sub-global assessment teams acknowledged that the very nature of stakeholder involvement is a creative and stimulating process, although the outputs can be highly unpredictable in terms of their value and usefulness to scenario activities. The main conclusion is that involving stakeholders, especially through workshops and meetings, is a very slow process that is resource-intensive. Other problems mentioned included:

- initially not all relevant stakeholders were selected (Caribbean Sea);
- serious cultural obstacles to effective scenario-building (PNG);
- stakeholders' unfamiliarity with radically different technologies (India Local);
- exogenous driving forces not of interest to participating communities (Trinidad);
- stakeholders have limited access to, and/or limited understanding of, information on processes at other scales (Caribbean Sea, India Local); and
- preoccupation with tangible outputs (Portugal).

These problems highlight the necessity of careful preparation before workshops and other information-gathering exercises.

10.7 Communication in Sub-global Scenarios

The issues of communication and participation are closely intertwined. If communication is viewed as advertising, then it is largely one-way, but if the aim is genuine and interested dialogue, then the possibilities of more symmetrical two-way exchanges, among stakeholder groups or between scientists and policy-makers, become real.

The development of scenarios involves two distinct forms of communication. One is the process of communication between scientists and other stakeholders that enables the scientists and other stakeholders to formulate alternative storylines. The other is the process by which the scientists then communicate these alternatives to an audience. This latter form of communication includes, but may not be restricted to, the stakeholders involved in the first process. The first process is communication *for* scenarios; the second process is communication *of* scenarios. The first process was addressed in the preceding section on participation, though primarily with an emphasis on the question of who participates, rather than the form of communication through which they participate. These two forms of communication—among experts and between experts and others—theoretically could be connected in an on-going process of dialogue by which scenarios are continually modified as a result of feedback from the stakeholders who participate in the initial construction, but this may not be feasible in practice because of resource constraints.

10.7.1 Communication Strategies

In relation to strategies adopted, the sub-global assessments can be divided into four groups:

- those that adopted specific forms of communication for both the development and dissemination of scenarios, and separated the communication of scenarios from the communication of the overall results of the assessment in order to address the needs and interests of specific user groups. Examples include the SAfMA local assessments and the Tropical Forest Margins assessments;
- those that used specific forms of communication with relevant stakeholders in the development of their scenarios, but did not separate the communication of these scenarios from the overall results of their assessments. The majority of sub-global assessments fall into this category;
- those that developed their initial scenarios without the active participation of relevant stakeholders, but still propose to develop distinctive forms of communication for the modification and dissemination of these scenarios. The PNG assessment seems to be the only one in this category (see Box 10.3);
- those that made little or no use of scenarios in their assessment—mostly because of budget constraints—and have not therefore adopted any specific forms of communication for this purpose. A good example of a sub-global assessment that did not have the resources to invest in communication was Coastal BC, which intended to use the interactive computer game QUEST (Tansey et al. 2002).

A minimal communication strategy would be one that embeds the results of scenario development in written reports addressed to an audience of scientists and policy-makers. Most assessments proposed to do this. Some went further than this, by communicating the results of the assessment (including scenarios) in a form that was suitable for ''consumption'' by other user groups, such as schoolchildren or illiterate members of local communities. The rest of this chapter focuses primarily on those cases in which scenarios have been, or will be, treated as a separate output of the assessment process.

10.7.2 Scenarios in Policy Dialogues

A number of sub-global assessments (for example, SAfMA, Tropical Forest Margins–Pan-Tropics, Western China) employed similar modes of communication with policy-makers and/or decision-makers at the beginning of their scenarios exercises and at the end when reporting the results. Reporting may be directed either to the same group of stakeholders involved in the original exercise, or to other groups at different levels in the policy-making process. This type of iterative communication normally involves a series of workshops or seminars in which scenarios are designed or analyzed with the aid of computer technology. For example, the Caribbean Sea scenarios will be used to guide the deliberations of ministers and senior officials engaged in the process of negotiating an intergovernmental management regime.

BOX 10.3

Obstacles to Communication: Papua New Guinea

The first (national) phase of the PNG assessment did not engage in a process of communication for scenario development, partly because of the limited budget allocated for work in this phase and partly because some relevant scenarios had already been developed in previous forms of policy dialogue at the national scale. These earlier scenarios were modified by the scientists engaged in the assessment in order to take account both of the global scenarios developed by the MA Scenarios Working Group and of the changing tenor of national debate about the country's political, economic, and environmental future, as reflected in the pages of the national press.

The scenarios developed in the national phase of the assessment will be used as an input to the communication process for further scenario development at the provincial and community scales in the second phase of the assessment. In this second phase, various communication techniques will be applied to the development of models and storylines at the national and community scales, and then to the task of communicating scenarios through an education and outreach program.

The outreach program is part of the community-based marine conservation project in which the assessment is embedded. The choice of techniques for communication will depend partly on the lessons already learned from other sub-global assessments and partly on the lessons learned from experiments with similar forms of communication in the southwest Pacific region. A well-known community theater group (based in Vanuatu) has produced a film about the effects of one driver (increasing population pressure) on ecosystem services and human well-being in one (imaginary) coastal local community. The national assessment report includes a brief evaluation of that process because of its potential applicability in future assessments.

PNG also includes the interesting observation that popular or community reactions to the process of scenario construction may be influenced, in some areas, by the prevalence of millenarian religious beliefs, especially when people are invited to include uncertainties or surprises or catastrophes in their storylines. This point underlines the importance of paying careful attention to the cultural context when designing a communication strategy for the development and dissemination of scenarios.

The Tropical Forest Margins assessments illustrate the way in which this type of communication is varied to accommodate the needs and interests of decision-makers at different levels in a policy process. For example, at the pan-tropic level, scenarios were developed to analyze the implications of biodiversity loss on hydrological functions. Constant iteration with a World Bank expert helped to delineate the focus of the results in order to effectively inform policy-makers. At the end of the project, the results were presented in a one-day policy seminar at the World Bank and are available at: http://www.asb.cgiar.org/BNPP/phase2/bnpp_phase2_general.htm. At the regional scale in Brazil, an economic equilibrium model was used to test the effects of devaluation on forest area in the Brazilian Amazon. The published results were mainly targeted at the regional government, as well as the national and international scientific communities. At the basin scale, Tropical Forest Margins–Mae Chaem tested different implications of hydrological functions by applying expert-driven scenarios; the results were communicated at the World Bank seminar, but also will be part of a wider strategy to translate the results to policy-makers throughout Southeast Asia. In Tropical Forest Margins–Western Brazil, data obtained at the local level were used to inform farm-level ''bioeconomic models'' in which the effects of different mixes of technological innovations were tested at different time horizons. The results were communicated to policy-makers through EMBRAPA, a Brazilian institute that is one of the partners in the Tropical Forest Margins consortium.

Stakeholder workshops and other types of face-to-face communication were used to disseminate the overall results of the SAfMA assessments at a number of different scales. SAfMA G-M presented verbal descriptions of its scenarios, first to local communities to elicit their responses (what they would do in each scenario) and then to local policy-makers to also elicit responses (what policies should be put in place). According to Tim Lynam (personal communication), who participated in these exercises, the community presentations were very successful and their responses were used in the assessment, whereas the policy presentations were not as successful.

10.7.3 Storylines for a Wider Audience

Stories about the future can be the most interesting and exciting way of communicating the results of an assessment to an audience that does not consist exclusively of scientists and policy-makers. However, there could be some incompatibility between the divergent needs of establishing the scientific credibility of alternative scenarios and communicating these scenarios effectively to a wider audience.

The SAfMA assessments followed the common practice of incorporating the analysis of scenarios into written materials that represented the overall results for the benefit of the different users represented on the advisory committees. This assessment went further than most in producing different types of documentation, from brochures to scientific journal articles, in order to address the needs and interests of different user groups, and hence to convince them of the usefulness of the assessment. However, while the communications strategy was thought to have been appropriate for the needs of policy-makers and planners in the public sector, it was recognized that communication with the general public was more problematic.

San Pedro de Atacama was the only assessment that developed specific media for communicating scenarios to schoolchildren. The assessment devised a process of familiarizing local children with the ecosystem that was being assessed, partly by engaging indigenous elders to provide informal lessons on recent ecosystem history. This exercise in oral history was expected to provide the basis for constructing plausible futures. In India Local, schoolchildren were also engaged in the process of data collection and monitoring, although the assessment did not include a separate communication of scenarios. PNG also used specific

media for communication with schoolchildren, but again not in the context of developing scenarios. In the Wisconsin assessment, booklet cartoon maps and illustrations were used to communicate the scenarios, though not necessarily only to young readers.

10.7.4 Spatial Representations of Scenarios

Spatial mapping or modeling techniques may be used as a distinctive form of communication in the development and dissemination of scenarios, but most sub-global assessments appear to have treated these as one aspect of the policy dialogue with a sophisticated audience of scientists and policy-makers, rather than a technique for securing popular participation or understanding.

At the local level, the Tropical Forest Margins–Cameroon assessment had villagers actively participating in the formulation of scenarios, using historic transects and creating graphics of the landscape futures across time. This was a form of participatory rural appraisal, which has been widely used in developing countries. In this particular case, the results were inconsistent with the scientific research findings on the investment strategies of local farmers.

In the case of Coastal BC, various stakeholders proposed emphasizing the use of mapping techniques to communicate the scenarios, as well as to record baseline data about the condition of ecosystem services and human well-being. Stakeholders asserted that mapping products would allow the users, including members of indigenous communities, to grasp the spatial and temporal scope of consequences emerging from their decisions. Investment in clear and effective techniques for the communication of scenarios was also thought to be a useful way of connecting the scientific and policy communities involved with the assessment. The application of these mapping techniques proved to be difficult, firstly because of technical problems with the software chosen for this purpose, and secondly because the methodology was not clearly understood by some of the stakeholders engaged in the initial process of communication. In other contexts, there might have been some resistance from indigenous communities to the idea of mapping their resources and placing these maps in the public domain, but this does not seem to have been an important obstacle in this case.

10.7.5 Community Theater and Video Techniques

The representation of scenarios by means of theatrical performances or film and video recordings is almost certainly the most powerful way of communicating ''plausible futures'' to a popular audience, but the human and financial resources available to the sub-global assessments limited the use of such techniques.

In the SAfMA Livelihoods assessment, a series of short plays representing alternative scenarios were performed before an audience drawn from one of the communities involved in the assessment process. Members of the community had some opportunity to participate in the process of scripting these plays before their performance, but had not been directly involved in the initial process of scenario development, which was based on communications with stakeholders at a higher level.

In this case, the communication of scenarios managed to accomplish the difficult task of dramatizing the content of a scientific report, but was essentially a feedback mechanism added on to the end of the assessment process. Like some other stakeholders in the assessment process, the audience was left to wonder what would happen after the scenarios had been communicated, but had at least been convinced that their own future was uncertain and that they could play a role in shaping it.

For SAfMA Livelihoods, the choice of media was dictated by the low levels of literacy in the community, and by the observation that local people were more likely to engage with messages conveyed through live performance than those conveyed through film. This still leaves open the question of how best to communicate scenarios to multiple communities living in similar circumstances, given the high transaction costs involved in the medium of community theater.

10.8 Findings of the Sub-Global Scenarios

Most of this chapter has focused on how the sub-global scenarios were developed. This section considers the findings they produced. It is an analysis of a selection of the resulting scenarios, concentrating on the main driving forces identified during scenario development, key processes described, the main ecosystem services included, and a cross-scale comparison of the scenarios results. The section first describes a few examples of how uncertainties and ecosystem services were treated, comparing among sub-global scenario findings. It then analyzes the scenario findings with respect to geographical scale and examines whether scale had any influence on the interpretation of scenario outcomes.

This section focuses only on those scenario exercises that were well advanced in at least their first iteration and that had therefore started to draw initial conclusions at the time of writing. The comparison mainly draws from the multi-scale SAfMA assessment, Caribbean Sea, India Local, and the first draft of scenarios from the Bajo Chirripó and Portugal assessments. It should be noted well that when more results become available, the conclusions drawn here might change slightly.

10.8.1 Commonalties among Scenario Findings

A comparison of similarities among major driving forces of change, key ecosystem services, and processes described by the sub-global scenarios can help to enhance understanding of how these forces work and interact. While the scenario exercises in many cases differed in their conclusions, a few common themes emerged. Governance was the one driving force that surfaced in almost all the scenario exercises considered. Biodiversity was another issue that a number of scenarios addressed because it relates to a number of ecosystem services.

10.8.1.1 Key Uncertainties: Governance

Governance issues were the only major uncertainty that surfaced in almost all scenario exercises considered. The nature of different governance regimes was used by many assessments as a major driving force to differentiate between scenario trajectories. In the multiscale SAfMA sub-global assessment, where the scenarios at different scales were developed independently, governance was identified as a key bifurcation at all scales. Social equity and the distribution of wealth was the second major axis of uncertainty in SAfMA.

In the scenarios built by the Caribbean Sea assessment, the main bifurcation that emerged centered on the issue of economic diversification: continued reliance on tourism as the main source of income for the region versus economic diversification to increase the resilience of economic systems. The issue of economic diversification in the Caribbean was strongly connected to a set of governance issues, such as regional cooperation, trade negotiations, and institution building.

The first set of national scenarios developed by the Portugal assessment identified the attitude of society toward the environment and its understanding of environmental change as one of the main driving forces. Here, an environmentally friendly attitude was translated into lifestyles and governance systems and institutions that try to find a balance between environmental protection and development. The second main driving force for these scenarios, land use measures and agricultural practices, were seen to be influenced by institutional structures and polices such as the Common Agricultural Policy of the European Union.

The draft scenarios for Bajo Chirripó also used governance as one major factor affecting the future of the indigenous communities in the area. Clarifying their rights under a new law that was discussed with the Costa Rican government at the time of the scenario exercise was described as one of the main bifurcation points for the future.

Besides governance, other factors, such as climate change at the global level or land use change at more local/regional levels, were also considered in various sub-global assessments. However, there was a much higher degree of variability among the other drivers considered by the sub-global assessments.

10.8.1.2 Key Ecosystem Services

The specific ecosystem services addressed varied widely among the various sub-global assessments. Table 10.6 lists some ecosystem services that were mentioned as being important. Two services immediately stand out: biodiversity and water quantity and quality. The prospects for biodiversity were clearly an important issue in many sub-global scenarios, being explicitly mentioned by five out of the eight sub-global assessments examined here. Water quantity and quality was also an important service, mentioned by six out of eight assessments. However, the water issue covered a large variety of different aspects including flooding, drought, irrigation, and salinity, drawing a picture that is less coherent than for biodiversity. A number of services were mentioned by only one or two sub-global assessments, including soil protection, tourism, and landscape aesthetics.

Table 10.6. Key Ecosystem Services Addressed in the Scenarios of Various Sub-global Assessments

Ecosystem Service	Sub-global Assessment
Biodiversity (pollination, pest control, genetic resources, habitat regeneration)	SAfMA, Caribbean Sea, Portugal, Bajo Chirripó, India Local
Water quality and quantity	Goulburn-Broken Catchment, Wisconsin, SAfMA, Portugal, Bajo Chirripó, San Pedro de Atacama
Soil protection	Portugal
Landscape aesthetics	Wisconsin, Portugal, San Pedro de Atacama
Recreation/Tourism	San Pedro de Atacama, Caribbean Sea

10.8.1.2.1 Biodiversity

Introducing policy and legal measures to protect biodiversity was seen in some regions as having a major impact on how biodiversity will be used in the future. Draft scenarios in both Portugal and India Local described this kind of response option to current biodiversity decline as major decision points. In Portugal, a move toward payments for environmental services to farmers due to changes in the EU CAP was seen as having a positive impact on biodiversity. In India, the introduction of a National Biodiversity Act opened up new prospects for biodiversity conservation, although it was recognized that the measure needed to be coupled with strengthening the institutional capacities for enforcing and monitoring the act and for collecting and managing data. At the same time resolving conflicts between developmental and biodiversity conservation goals at the local level were seen as an important challenge in the future.

Climate change was seen to hold significant uncertainties for biodiversity in a number of scenario exercises. Changing sea temperatures in the Caribbean are likely to influence primary production and may have surprising effects on populations of fish, corals, and other keystone species. Climate change is also an important stressor for southern African ecosystems. But even without accounting for its impacts, in all SAfMA Regional scenarios, biodiversity will decline over the next three decades, although the rate of decline and expected level of stabilization differ depending on the scenario assumptions.

Technological development was described in Caribbean Sea as having the potential to change the regional status quo for biodiversity in novel and possibly unexpected ways. Better bioprospecting technologies could lead to increased pharmaceutical involvement in several poorer regions of the world. In the Caribbean, the implications of better fishing technologies and fish-tracking devices, such as allowing greater and more selective exploitation of fish stocks for food, were explored. Improvements in monitoring and enforcement technology make it easier to manage fish stocks sustainably.

10.8.1.2.2 Water

Water quality and quantity are other examples of ecosystem services addressed explicitly in many sub-global assessments. While in Wisconsin, for example, water quality was of particular importance, the San Pedro de Atacama and the SAfMA scenario exercises focused mainly on water availability, with each identifying a threat to the availability of water resources in their respective areas.

These are but examples of the variety of ecosystem services that were considered. Even when categorized under the same common denominator, the focus was often different in different places, while in most sub-global assessments at least one ecosystem service was unique. The list of ecosystem services will undoubtedly grow as more sub-global assessments produce results, but it is also anticipated that most sub-global scenario exercises will include common ecosystem services such as water, biodiversity and possibly tourism.

10.8.2 Comparing Findings across Scales

10.8.2.1 Differences in Scenarios across Scales

Table 10.7 shows how three sub-global scenarios exercises (SAfMA, Caribbean Sea, and Portugal) can be mapped onto the MA global scenarios exercises based on the common elements among them. The process of how the specific scenarios were developed differed between the exercises; however, they all contain specific aspects that also occur in the global scenarios. These include either common basic storyline elements across the exercises (that appear for example in both the global MA scenarios and the Portugal scenarios) or similar assumptions and ideas (for example, a globalized versus a fragmented world), such as in the global MA, SAfMA, and Caribbean Sea scenarios. Our analysis shows that a number of common themes can be found across scales. These themes could be interpreted and played out differently at each geographical level, as the comparison between the Caribbean Sea and the MA global scenarios demonstrates. Both exercises used the degree of interconnectedness with the world as one of the main differences between the portrayed future worlds.

10.8.2.2 Differences in Perceptions across Scales

One interesting outcome of comparing the scenarios across scales is that the analysis reveals how the interpretation of scenario outcomes by stakeholders can differ across scales. What is seen as a beneficial outcome by stakeholders at one scale can be interpreted differently by stakeholders at another scale.

The Portugal assessment describes this tension in a comparison of its national and local scenarios: One local scenario in Portugal is characterized by the abandonment of agricultural fields and rural outmigration. Agricultural terraces are replaced by oak forests, with the loss of local provisioning services but a likely improvement in biodiversity. For local policy-makers this land abandonment scenario is undesirable. However, in the national and global context, the scenario could be part of a Global Orchestration type scenario (described in Appendix 10.1), which is viewed by policymakers at these coarser scales as having the highest direct benefits to human well-being.

The Caribbean Sea scenarios demonstrate this difference in scenario interpretations as well. The Caribbean region is considered particularly vulnerable to external forces because of its current and historically high reliance on international markets and capital, and the effects of economies of scale on small islands and developing states. While a well-connected world that emphasizes the equitable distribution of wealth may hold benefits for poorer regions of the world, it also holds substantial risks. For the Caribbean region, which is already highly connected to international markets and is particularly dependent on international tourism, a Global Orchestration-type scenario would most likely result in further dependence on these external markets. A change in

Table 10.7. Cross-mapping of SAfMA, Caribbean Sea, and Portugal Scenarios onto the MA Global Scenarios

	SAfMA Scenarios				Caribbean Sea Scenarios	Portugal Scenarios		
MA Global Scenarios	**Regional**	**Gariep**	**Livelihoods**	**Gorongosa-Marromeu**		**National (first phase)**	**National (second phase)**	**Sistelo (local)**
Global Orchestration	African Partnership	Policy Reform	Betterment	Devolution	Neo-plantation-Economy	Evolution of Continuity	*Global Orchestration* (downscaled)	Abandonment
		Market Forces	Green Engineering	Patronage				
Techno Garden					Quality over Quantity	Celestial Portugal	*Techno Garden* (downscaled)	
Adapting Mosaic	African Patchwork	Local Resources	Stagnation		Diversify Together	Bucolic Portugal	*Adapting Mosaic* (downscaled)	Rejuvenation
Order from Strength		Fortress World			Growing Asymmetries	Portugal at its Worst	*Order from Strength* (downscaled)	

tourism activities for any reason, and particularly if it were abrupt, would have significant negative impacts on the region's economy.

Another example can be taken from SAfMA. The multiscale structure of the SAfMA assessments showed that certain responses or developments at coarser scales are experienced as surprises or shocks at local scales (for example, if mega parks and large irrigation schemes are implemented without adequate local stakeholder participation and consideration of impacts). The SAfMA regional and local scale scenarios also suggest that general trends in ecosystem services at the regional and basin-scale may be reversed in particular local situations. The SAfMA results are also interesting with respect to comparing global and regional interpretations of scenario outcomes. The greatest direct benefits to human well-being are generally expected under scenarios corresponding to the Global Orchestration scenario. However, a key uncertainty in southern Africa is the degree of social equity that would prevail under this scenario. While economies are expected to strengthen, the degree to which the benefits of economic growth are distributed within society is seen as an important bifurcation point, as evidenced by the different variations of the Global Orchestration scenario in SAfMA Regional. Without specific emphasis on policies that ensure social equity, it appears unlikely that economic growth will hold substantial benefits for the poor. The SAfMA results here reinforce one of the messages of the Global Orchestration scenario.

These examples show that the comparison of scenario interpretations across scales can reveal useful insights for developing response options for different stakeholders under the various scenarios developed. They show where differences between stakeholder priorities or worldviews lie, and can therefore be used to analyze potential areas of conflict between them.

10.8.3 Summing Up: The Importance of Stakeholders

The comparison of findings across the sub-global scenario exercises reveals more differences than commonalities in specific results. Given the high degree of variability among the sub-global assessments that were considered here, this was to be expected. Nevertheless a number of emerging common themes can be used to ground-truth coarser scale scenarios. In particular, the importance of governance as a main driver in all sub-global assessments should be checked against assumptions in the global storylines.

More importantly, the set of scenarios for which results were available showed that each strategy has winners and losers, which vary depending on the scale examined. Scenarios that appear beneficial at the national scale may hold substantial losses and threats for certain communities at finer scales. Identification of winners and losers in each scenario is an important step in guiding future responses. The inclusion of stakeholders in scenario development and validation processes helps make explicit the circumstances under which winners and losers emerge. The comparison of scenario findings across scales also demonstrates that scenario interpretations differ across scales. In the context of the purposes and methods employed to develop scenarios, directly involving end-users and stakeholders in the process, these conclusions suggest a need for more comprehensive engagement with users and a more systematic analysis of their perceptions.

10.9 Conclusions and Recommendations for Future Assessments

10.9.1 Strength in Diversity

The MA sub-global assessments comprise a unique collection of scenario-building experiences covering several continents and a wide variety of local, national, and regional contexts. The most outstanding feature of this collection is the diversity of goals and of approaches to building, refining, and communicating scenarios. At the same time, the various assessment groups have kept the goals of assessing ecosystems services and human well-being largely in focus. ***The lesson is that there is no single clearly superior way to conduct scenarios.*** As noted, constructing storylines using one or two main uncertainties as axes worked well for some assessments, but inhibited creativity for some others. Prospective scenario-builders and users can reflect upon a list of questions, such as the ones shown in Figure 10.1, to guide their processes. This final section highlights some important points not fully considered in previous sections.

10.9.2 Lessons Learned

The most significant strength of the entire endeavor is the common methodology that links all sub-global assessments. Given the variety of assessments, important conclusions on how best to construct scenarios can be drawn. Already discussed were recommendations on how linking global and sub-global scenarios could be made successful, and when there are good reasons not to attempt a complete link. Similar recommendations follow in this section for other methodological aspects, such as stakeholder involvement. Engaging local stakeholders is another important strength of most sub-global assessments. In particular, the use of participatory approaches, and thus the incorporation of key decision-makers in the process, was attempted in most assessments.

A problem encountered by all assessments was the relatively poor link between the various sub-global scales. All assessments recognized the importance of nesting across scales, and all devoted some attention to key factors at different scales. However, few assessments focused on cross-scale interactions and feedbacks, with the notable exceptions of SAfMA Regional and planned work in Portugal. In most assessments, the emphasis was at the level of decision-making, in other words at the political or social scale, rather than the ecological scale (scales of time and space). It has not been possible in this chapter to cover all aspects of political/social scale and ecological scale, and it is expected that the two will not always coincide.

10.9.2.1 Integrating Scenarios with other Assessment Components

The degree to which the scenario-based activities in the assessments were linked to efforts to assess conditions and trends, or explore responses, varied greatly among sub-global assessments. Integration was excellent for a number of sub-global assessments, such as San Pedro de Atacama (management options) and SAfMA (condition and trends), but could have been improved for many others. A number of sub-global assessments, including SAfMA Regional, acknowledged specifically that scenarios were a relatively small part of the assessment. Some assessments regarded scenarios primarily as a useful *tool* to communicate with local decision-makers rather than as a result in their own right. Elevating the importance of scenario development could have consequences for methods employed, such as stakeholder selection, scale selection, and dealing with uncertainties.

Nevertheless, the use of narrative scenarios developed through participatory methods is relatively new to the scientific world, and therefore full realization of the potential gains should not yet be expected. It should be noted that scenario development is being assigned increasing importance in the process of testing the robustness of policy measures, and was prominent in many sub-global assessments (including Portugal, SAfMA Regional, and Sweden). The connection between this type of scenario analysis and other analyses, however, is still rather weak. A method to link qualitative stories to quantitative models is clearly needed, although some progress is being made in the sub-global assessments in Western China, Downstream Mekong, and Laguna Lake Basin. More attempts and examples are needed to convince future sub-global assessments that scenario development extends the quantitative or forecasting methods in a positive and meaningful way, and that it also helps decision-makers to think, talk, plan, and act imaginatively in pursuit of a more sustainable society.

10.9.2.2 Improving the Link between Global and Sub-global Scenarios

The greatest challenge in trying to link global and sub-global scenarios is increasing understanding in many (very local) assessments of how such large-scale developments can be translated to the local level. There are many solutions to bridge this gap between global and local. Most of them involve a ''translation'' of the global scenarios to make them more applicable to the local situation:

- *Translate ''facts'' to ''feelings.''* Local stakeholders will be less overwhelmed by global developments if they are not presented as facts but as underlying assumptions and (changes in) worldviews. For instance, the presentation of the Techno Garden scenario could focus more on ''society's ability to invent'' (see Appendix 10.1) and less on technical solutions that are imposed on a reactive society.
- *Translate all multiscale aspects*. Developments have to be presented to local stakeholders not only for a smaller geographical region, but also for shorter time scales and for shorter human decision-making scales. Local stakeholders do not relate as easily to the effects of global warming, as they would to three consecutive years of drought.

The need for translation relates directly to the primary goal for which scenarios are constructed. At the global level, scenarios are mainly used as a communication tool and to inform decision-making on important future trends and uncertainties. At the local level, scenarios have been utilized more as a direct tool for engaging people from different sectors of society, and leveraging expertise in decision-making processes. In general, the more local the scale, the more scenarios become a tool for empowerment.

The above implies that the challenge lies both with the sub-global assessments that need to make an effort to downscale global storylines, and with the global assessments that could improve the manner in which their scenarios are presented. Scenarios developed both at global and sub-global scales could have benefited from some additional iteration. Only with these methodological efforts can we begin to link the rich variety of local and regional stories and global developments.

Despite the complexity that these mismatches introduce and the fact that ''multiscale'' considerations are not always important for each sub-global assessment, the MA effort has stimulated renewed interest in the potential for multiscale scenario development. It potentially has much greater local policy relevance than most previous global environmental assessments.

10.9.2.3 Regional Diversity, Multiple Scales, and Ecology

The diversity of local and regional scenarios being developed by the sub-global assessments represents a major challenge to the global assessment community and it may often be difficult, and even counter-productive, to tightly constrain (or link) scenarios developed at these sub-global levels with those at higher or lower levels. On the other hand, checking for inconsistencies in major assumptions (''discordances across scale'') may help interpret regional variation and improve scenarios at both global and sub-global scales. How much attention needs to be paid to these cross-scale concerns ultimately depends on how inconsistent the key processes of change are for the particular ecosystem services assessed.

In most sub-global assessments, the interactions between ecosystems, their services, and human well-being were rather poorly documented, and their incorporation in the scenarios was relatively insignificant. There are difficult decisions to be made in the design of scenario exercises, between focusing on a few services that can well be understood and trying to realize a better appreciation of interaction between a wider range of services in a more comprehensive, but less detailed assessment. The currently advocated methods of developing holistic, integrated, participatory scenarios might not be the best to address the objective of the scenario exercises. When the main objective of developing scenarios is direct decision support, and the uncertainties and possible futures are pre-defined, complex participatory processes may, in particular, be unnecessary.

10.9.2.4 Concluding Remarks

There are four main conclusions from this chapter, based on the unique source of information that the large and growing number of sub-global assessment scenarios represent:

- Of all the approaches to conducting scenarios, none is clearly superior to the others.
- Sub-global scenarios allow for the critical evaluation of local variations that cannot be properly assessed at the global scale alone.
- Scenarios developed at global and sub-global scales could have benefited from additional iteration and interaction across scales. Only with additional methodological efforts can we begin to link the rich variety of sub-global and global scenarios.
- In relation to global assessment frameworks, the MA is unusual in its emphasis on ecology. Even so, future scenario activities should pay even greater attention to ecological processes.

Finally, we must acknowledge that the level of skill in conducting scenario exercises and then integrating these with assessments of conditions and trends, and response options, is still growing. The sub-global assessments represent a heterogeneous collection of approaches, focal issues, and scales, which is an encouraging start for much more experimentation with scenarios and related future-exploring methods.

Appendix 10.1. Summary of Global Scenarios in the Millennium Ecosystem Assessment

The *Global Orchestration* scenario depicts a globally connected society in which policy reforms that focus on global trade and economic liberalization are used to reshape economies and governance, emphasizing the creation of markets that allow equitable participation and provide equitable access to goods and services. These policies, in combination with large investments in global public health and the improvement of education worldwide, generally succeed in promoting economic expansion and lifting many people out of poverty into an expanding global middle class. Supranational institutions in this globalized scenario are well placed to deal with global environmental problems such as climate change and fisheries decline. However, the reactive approach to ecosystem management makes people vulnerable to surprises arising from delayed action. While the focus is on improving the well-being of all people, environmental problems that threaten human well-being are only considered after they become apparent. Growing economies, expansion of education, and growth of the middle class lead to demands for cleaner cities, less pollution, and a more beautiful environment. Rising income levels bring about changes in global consumption patterns, boosting demand for ecosystem services, including agricultural products such as meat, fish, and vegetables. Growing demand for these services leads to declines in other ones, as forests are converted into cropped area and pasture and the services they formerly provided decline. The problems related to increasing food production, such as loss of wildlands, are not apparent to most people who live in urban areas. They therefore receive only limited attention. Global economic expansion expropriates or degrades many of the ecosystem services poor people once depended on for survival. While economic growth more than compensates for these losses in some regions by increasing the ability to find substitutes for particular ecosystem services, in many other places, it does not. An increasing number of people are affected by the loss of basic ecosystem services essential for human life. While risks seem manageable in some places, in other places there are sudden, unexpected losses as ecosystems cross thresholds and degrade irreversibly. Loss of potable water supplies, crop failures, floods, species invasions, and outbreaks of environmental pathogens increase in frequency. The expansion of abrupt, unpredictable changes in ecosystems, many with harmful effects on increasingly large numbers of people, is the key challenge facing managers of ecosystem services.

The *Order from Strength* scenario represents a regionalized and fragmented world that is concerned with security and protection, emphasizes primarily regional markets, and pays little attention to common goods. Nations see looking after their own interests as the best defense against economic insecurity, and the movement of goods, people, and information is strongly regulated and policed. The role of government expands as oil companies, water utilities, and other strategic businesses are either nationalized or subjected to more state oversight. Trade is restricted, large amounts of money are invested in security systems, and technological change slows due to restrictions on the flow of goods and information. Regionalization exacerbates global inequality. Treaties on global climate change, international fisheries, and trade in endangered species are only weakly and haphazardly implemented, resulting in degradation of the global commons. Local problems often go unresolved, but major problems are sometimes handled by rapid disaster relief to at least temporarily resolve the immediate crisis. Many powerful countries cope with local problems by shifting burdens to other, less powerful ones, increasing the gap between rich and poor. In particular, natural resource–intensive industries are moved from wealthier nations to poorer, less powerful ones. Inequality increases considerably within countries as well. Ecosystem services become more vulnerable, fragile, and variable in *Order from Strength*. For example, parks and reserves exist within fixed boundaries, but climate changes around them, leading to the unintended extirpation of many species. Conditions for crops are often suboptimal, and the ability of societies to import alternative foods is diminished by trade barriers. As a result, there are frequent shortages of food and water, particularly in poor regions. Low levels of trade tend to restrict the number of invasions by exotic species; ecosystems are less resilient, however, and invaders are therefore more often successful when they arrive.

In the *Adapting Mosaic* scenario, regional watershed-scale ecosystems are the focus of political and economic activity. This scenario sees the rise of local ecosystem management strategies and the strengthening of local institutions. Investments in human and social capital are geared toward im-

proving knowledge about ecosystem functioning and management, which results in a better understanding of resilience, fragility, and local flexibility of ecosystems. There is optimism that we can learn, but humility about preparing for surprises and about our ability to know everything about managing ecosystems. There is also great variation among nations and regions in styles of governance, including management of ecosystem services. Some regions explore actively adaptive management, investigating alternatives through experimentation. Others use bureaucratically rigid methods to optimize ecosystem performance. Great diversity exists in the outcome of these approaches: some areas thrive, while others develop severe inequality or experience ecological degradation. Initially, trade barriers for goods and products are increased, but barriers for information nearly disappear (for those who are motivated to use them) due to improving communication technologies and rapidly decreasing costs of access to information. Eventually, the focus on local governance leads to failures in managing the global commons. Problems like climate change, marine fisheries, and pollution grow worse, and global environmental problems intensify. Communities slowly realize that they cannot manage their local areas because global and regional problems are infringing on them, and they begin to develop networks among communities, regions, and even nations to better manage the global commons. Solutions that were effective locally are adopted among networks. These networks of regional successes are especially common in situations where there are mutually beneficial opportunities for coordination, such as along river valleys. Sharing good solutions and discarding poor ones eventually improves approaches to a variety of social and environmental problems, ranging from urban poverty to agricultural water pollution. As more knowledge is collected from successes and failures, provision of many services improves.

The *TechnoGarden* scenario depicts a globally connected world relying strongly on technology and highly managed, often engineered ecosystems to deliver ecosystem services. Overall efficiency of ecosystem service provision improves, but it is shadowed by the risks inherent in large-scale humanmade solutions and rigid control of ecosystems. Technology and market-oriented institutional reform are used to achieve solutions to environmental problems. These solutions are designed to benefit both the economy and the environment. These changes co-develop with the expansion of property rights to ecosystem services, such as requiring people to pay for pollution they create or paying people for providing key ecosystem services through actions such as preservation of key watersheds. Interest in maintaining, and even increasing, the economic value of these property rights, combined with an interest in learning and information, leads to a flowering of ecological engineering approaches for managing ecosystem services. Investment in green technology is accompanied by a significant focus on economic development and education, improving people's lives and helping them understand how ecosystems make their livelihoods possible. A variety of problems in global agriculture are addressed by focusing on the multifunctional aspects of agriculture and a global reduction of agricultural subsidies and trade barriers. Recognition of the role of agricultural diversification encourages farms to produce a variety of ecological services rather than simply maximizing food production. The combination of these movements stimulates the growth of new markets for ecosystem services, such as tradable nutrient runoff permits, and the development of technology for increasingly sophisticated ecosystem management. Gradually, environmental entrepreneurship expands as new property rights and technologies co-evolve to stimulate the growth of companies and cooperatives providing reliable ecosystem services to cities, towns, and individual property owners. Innovative capacity expands quickly in developing nations. The reliable provision of ecosystem services as a component of economic growth, together with enhanced uptake of technology due to rising income levels, lifts many of the world's poor into a global middle class. Elements of human well-being associated with social relations decline in this scenario due to great loss of local culture, customs, and traditional knowledge and the weakening of civil society institutions as an increasing share of interactions take place over the Internet. While the provision of basic ecosystem services improves the well-being of the world's poor, the reliability of the services, especially in urban areas, become more critical and is increasingly difficult to ensure. Not every problem has succumbed to technological innovation. Reliance on technological solutions sometimes creates new problems and vulnerabilities. In some cases, societies seem to be barely ahead of the next threat to ecosystem services. In such cases new problems often seem to emerge from the last solution, and the costs of managing the environment are continually rising. Environmental breakdowns that affect large numbers of people become more common. Sometimes new problems seem to emerge faster than solutions. The challenge for the future is to learn how to organize socioecological systems so that ecosystem services are maintained without taxing society's ability to implement solutions to novel, emergent problems.

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