Biggs, R., C. Raudsepp-Hearne, C. Atkinson-Palombo, E. Bohensky, E. Boyd, G. Cundill, H. Fox, S. Ingram, K. Kok, S. Spehar, M. Tengö, D. Timmer, and M. Zurek 2007. Linking futures across scales: a dialog on multiscale scenarios. *Ecology and Society* **12**(1): 17. [online] URL: http://www.ecologyandsociety.org/vol12/iss1/art17/

Young Scholars Dialogue, part of a Special Feature on Scenarios of global ecosystem services

Linking Futures across Scales: a Dialog on Multiscale Scenarios

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ABSTRACT. Scenario analysis is a useful tool for exploring key uncertainties that may shape the future of social-ecological systems. This paper explores the methods, costs, and benefits of developing and linking scenarios of social-ecological systems across multiple spatial scales. Drawing largely on experiences in the Millennium Ecosystem Assessment, we suggest that the desired degree of cross-scale linkage depends on the primary aim of the scenario exercise. Loosely linked multiscale scenarios appear more appropriate when the primary aim is to engage in exploratory dialog with stakeholders. Tightly coupled cross-scale scenarios seem to work best when the main objective is to further our understanding of cross-scale interactions or to assess trade-offs between scales. The main disadvantages of tightly coupled cross-scale scenarios are that their development requires substantial time and financial resources, and that they often suffer loss of credibility at one or more scales. The reasons for developing multiscale scenarios and the expectations associated with doing so therefore need to be carefully evaluated when choosing the desired degree of cross-scale linkage in a particular scenario exercise.

Key Words: *multiscale scenarios; cross-scale scenarios; stakeholder engagement; Millennium Ecosystem Assessment; environmental assessment; scenario analysis*

INTRODUCTION

First used as a method for war game analysis after World War II (Kahn and Wiener 1967, Shoemaker 1993, van der Heijden 1996), scenario analysis is now applied in a wide variety of contexts, such as political decision making (e.g., Galer 2004*a*, Kahane 2004), business planning (e.g., Wack 1985, Davis 1998), and environmental management (e.g., Alcamo 2001, Wollenberg et al. 2000). Scenarios are plausible stories about how the future might unfold, constructed using qualitative and/or quantitative models and information on current and past conditions. Scenarios are distinguished from other approaches to future assessment, such as forecasting and risk assessment, by being specifically intended for situations in which the factors shaping the future are highly uncertain and largely uncontrollable (Fig. 1). The aim of scenario planning is specifically to consider a variety of possible futures, rather than to focus on the accurate prediction of a single outcome (Clark et al. 2001, Bennett et al. 2003, Peterson et al. 2003*b*).

Scenario analysis has emerged as a particularly useful tool for considering the linked development trajectories of ecosystems, ecosystem management, and human well-being, also known as social-ecological systems (Gallopin et al. 1997, Peterson et al. 2003*b*, Carpenter et al. 2005). Scenarios allow us to envision alternative future development pathways by taking a systems perspective and accounting for critical uncertainties such as far-reaching technological changes or changes in social values. By envisioning alternative futures, scenarios can help decision makers identify ecosystem management policies and actions that will be robust across a range of potential future outcomes, or that promote desired outcomes or characteristics, such as ecosystem resilience (Shearer 2005, Carpenter and Folke 2006). Many scenario exercises use a participatory process to develop the scenario storylines. Particularly in these cases, scenario analysis can be a powerful tool to facilitate and increase understanding, knowledge sharing, and communication among stakeholders, defined as those involved in or affected by the management of

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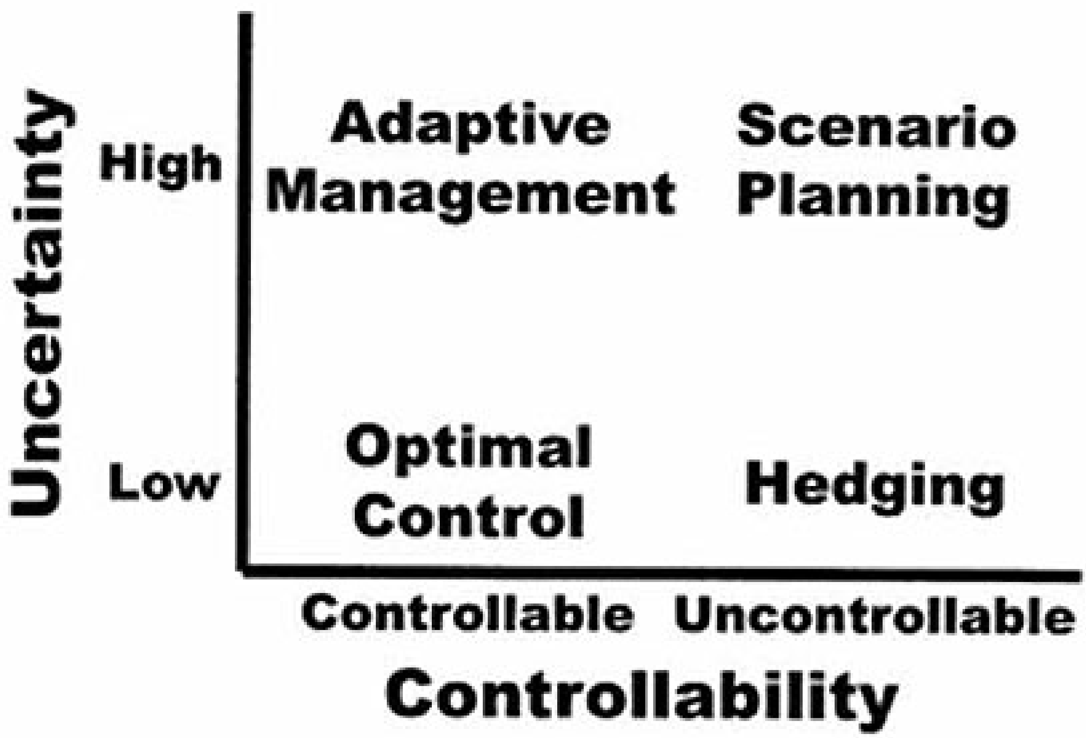
Fig. 1. Scenario planning is most appropriate under conditions of high uncertainty and when the forces driving that uncertainty are largely uncontrollable (figure from Peterson et al. 2003*a*).



the ecosystems in a particular region (Wollenberg et al. 2000, van den Belt 2004, Lebel et al. 2005). Scenario analysis can be an effective way of engaging stakeholders who might otherwise be unresponsive to scientific information presented in more traditional forms such as scientific articles or reports.

Scenarios have been used to consider future changes in social-ecological systems at scales ranging from local villages through to the entire globe (e.g., IGD and FESSA 2002, Carpenter et al. 2005, Lebel et al. 2005, Alcamo et al. 2006). By "scale" we mean the spatial extent of a particular scenario exercise, so that "national scale" refers to a scenario exercise that covers the extent of a nation. The spatial extent of a scenario exercise is often defined to coincide with the specific levels of social organization involved in ecosystem management, such as local villages or national and global entities (e.g., UNEP 2002*a*, Carpenter et al. 2005). An increasing number of scenario studies can be labeled as "multiscale." These refer to exercises that consist of a set of linked scenarios constructed at two or more scales. Although most of the scenarios conducted at a single scale engage stakeholders and consider factors operating at multiple scales, we do not consider these to be multiscale scenarios. In a multiscale scenario exercise, storylines are developed at several scales, e.g., global and national, and are linked to one another to some degree. At one extreme, storylines at different scales may be largely developed independently and only loosely linked. At the other extreme, the storylines may be developed in a tightly coupled, iterative fashion so that they are consistent across scales and incorporate cross-scale feedbacks.

The motivations for developing multiscale scenarios are to engage stakeholders and help understand driving forces, processes, perspectives, and responses at multiple scales (Lebel et al. 2005). Multiscale scenarios can better maintain relevance across multiple decision-making scales than, for instance, a single-scale global exercise, and thereby potentially enhance stakeholder engagement and use of the scenario results. The development of multiscale scenarios may facilitate increased communication among stakeholder groups or decision makers at different scales and increase our appreciation of differences in stakeholder concerns or perspectives (Wollenberg et al. 2000). Furthermore, social, political, economic, and ecological processes can often be more readily observed, or have stronger impacts, at some scales than others (MA 2003). Multiscale scenario exercises can highlight these differences. Cross-scale interactions, which are important in social-ecological systems (Wilbanks and Kates 1999, Berkes 2002, Gunderson and Holling 2003), can also be better considered in multiscale scenarios. Finally, multiscale scenarios make it easier to examine the impacts of mismatches between the scale at which ecological processes occur and the scale at which management occurs (Folke et al. 1998, Brown 2003).

This paper explores the methods, opportunities, and barriers associated with developing multiscale scenarios. We focus on scenarios that consider complex, inter-related changes in social-ecological systems (Berkes et al. 2003). The paper stems from a one-month online dialog among the authors and draws on their perspectives and experiences with scenario development and ecosystem management. We specifically aim to synthesize our key ideas and intuitions about the multiscale scenario development process, because this tacit knowledge is often not reflected in formal scenario reports and research papers. The authors come from diverse disciplinary backgrounds including ecology, conservation biology, geography, environmental science, anthropology, and environmental economics. Many of the authors were involved in the local, regional, or global scenario development exercises of the Millennium Ecosystem Assessment (Carpenter et al. 2005, Lebel et al. 2005), which aimed to assess the consequences of ecosystem change for human well-being at multiple scales. We have attempted to broaden the base for our conclusions by considering additional scenario exercises, particularly the limited number that include a multiscale aspect. These include the Global Environmental Outlook scenarios (UNEP 2002*a*), which have been used in regional assessments in Africa (UNEP 2002*b*), Latin America, and the Caribbean (UNEP 2003); the Intergovernmental Panel on Climate Change emissions scenarios (Nakišenoviš et al. 2000), which have been used, for instance, to develop land-use change scenarios for Europe (Schröter et al. 2006, Verbrug et al. 2006, Westhoek et al. 2006) and climate scenarios for the UK (Hulme et al. 2002); and the MedAction scenarios that used the European level VISIONS project scenarios (Rotmans et al. 2000, 2005) to explore land degradation in the Mediterranean region (Kok et al. 2006*a*,*b*).

HOW DOES SCALE INFLUENCE SCENARIO DEVELOPMENT AND STAKEHOLDER ENGAGEMENT?

Scenarios range widely in their goals, content, and development methods (Table 1). Based on our examination of scenario studies, it appears that the scenario development approach adopted at a particular scale depends primarily on the goals of the exercise, the participants involved in the actual scenario development, the social and political context, and the resources available for the scenario exercise.

Broadly speaking, scenarios may be designed primarily for exploratory purposes or primarily for decision support. The primary focus of exploratory scenarios is to understand alternative development trajectories and the impacts and interactions of the key forces driving change. Exploratory scenarios typically use the present or recent past as a starting point and explore how the future may develop under different sets of assumptions. The Millennium Ecosystem Assessment (MA) global scenarios (Carpenter et al. 2005) are an example of a scenario exercise that was primarily exploratory: it sketched out four plausible future worlds to 2050 and analyzed the implications for ecosystem services.

Decision support scenarios are more narrowly focused on developing or testing specific policies. They often use the outcome of an exploratory scenario exercise as a framework. For example, the UK's Foresight Programme develops several visions of the future that are then used to identify potential opportunities for new science and technologies or to consider how science and technology could address future societal challenges (SPRU 2002). The Royal Dutch Shell group uses

Table 1. Several major axes of variation characterize the diversity of purpose and approaches adopted in scenario exercises. The two columns represent the ends of a continuum. Most scenario exercises lie between these endpoints. Note that the different axes do not necessarily co-vary, i.e., the elements in each column need not co-occur. For example, an exploratory scenario could be motivated by either scientific inquiry or policy support (table adapted from Ducot and Lubben 1980, Bunn and Salo 1993, Wollenberg et al. 2000, van Notten et al. 2003).

Dimensions along which scenarios vary	Range of variation		
Purpose	Exploratory, investigate uncertainties and drivers of change	↔	Decision support, test robustness of policies
Motivation	Scientific inquiry	↔	Policy support
Focus	On process: development of storylines	↔	On outcome: implications of storylines for decision making
Inclusion of norms	Normative, e.g., scenarios reflect the desired and “good” or the undesired and “bad”	↔	Descriptive, not based on social preferences
Approach	Quantitative, “hard,” formal models: statistical forecasting, trend-impact analysis, cross-impact analysis	↔	Qualitative, “soft” methods: visioning, intuitive logic, storytelling
Source of information	Formal, rational, scientific observation	↔	Judgment and intuition of decision makers, intuitive, local knowledge systems and world views
Level of uncertainty	Low	↔	High
Number of focal scales	Single scale	↔	Multiple scales
Links between scales	Loosely linked: perspectives, uncertainties, and drivers from each scale partially inform scenario exercises at other scales	↔	Tightly coupled: perspectives, uncertainties, and drivers from each scale strongly inform the scenario exercises at other scales
Number of storylines	One	↔	Multiple (3–9, typically 3–5)
Starting point of storyline	Future, uses backward inference or “backcasting,” deductive	↔	Present, uses future inference, inductive, builds from knowledge of roles and environmental trends
Endpoint of storyline	“Snapshot” at one future point in time	↔	Story of events linked from present to future
Driving forces	Underlying (exogenous, external): hard or impossible to control by stakeholders	↔	Proximate (endogenous, internal): controllable to some extent by stakeholders
Dynamics	Simple	↔	Complex, includes thresholds and feedbacks
Stakeholders as participants	Active participants in construction and evaluation, i.e., participatory scenarios	↔	Passive objects of analysis, i.e., expert-driven scenarios
Stakeholders as audience	No communication strategy in mind	↔	Targeted communication strategy integral to design, e.g., policy briefings, drama, editorials

scenarios as "wind tunnels" to explore the robustness of long-term business strategies across a range of plausible future business environments (Royal Dutch Shell 2005). Decision support scenarios can also be used in a backcasting method to explore alternative routes by which some desirable or agreed-upon target may be reached. For instance, the International Food Policy Research Institute has used a backcasting approach to explore the requirements for achieving the Millennium Development Goals on poverty in Ethiopia and Zambia (Rosegrant et al. 2006).

To date, environmental scenario exercises at the global scale have tended to be more exploratory in nature, with a strong focus on delivering scientifically rigorous quantitative outputs. Much effort has been invested in the development and parameterization of the large, complex models needed to deliver these outputs. For example, the purpose of the Intergovernmental Panel on Climate Change (IPCC) scenarios was to provide quantitative estimates of possible future greenhouse gas emissions (Nakišenoviš et al. 2000) using models such as the Integrated Model to Assess the Greenhouse Effect or IMAGE (Alcamo et al. 1998). Other examples of global environmental scenarios with a quantitative focus include the World Water Vision scenarios (Cosgrove and Rijsberman 2000), the Global Environmental Outlook (GEO) scenarios (UNEP 2002*a*), and the MA global scenarios (Carpenter et al. 2005). Partly as a consequence of their strong quantitative focus, global-scale exercises have tended to be expert driven, involving stakeholders and decision makers through extensive review processes rather than in the actual scenario development workshops. The stakeholders involved usually include influential people such as governmental officials, NGO groups, academics, and representatives of large corporations (Evans et al. 2006); they seldom directly include local resource users such as farmers.

In contrast, many local-scale scenario exercises have emphasized the process of communication and consensus-building among stakeholders that may accompany scenario development. For example, in the Mae Khong Kha watershed in Thailand, conflict exists between the upstream and downstream communities because of stream pollution resulting from rice paddy cultivation and high-input maize monocultures in the upstream region (Lebel et al. 2005; P. Thongbai, D. Pipattwattanakul, P. Preechapanya, and K. Manassrisuksi, *unpublished manuscript*). A series of participatory scenario workshops involving stakeholders representing both the upstream and downstream communities was instrumental in developing consensual, community-driven policy recommendations for resolving the conflict. The use of scenarios as a tool to air conflicts or build consensus among diverse stakeholders has been proposed as part of the development of catchment management strategies under South Africa's new water law (Rogers et al. 2000). In such participatory exercises, the outcomes and implications of the actual storylines are often less important than the knowledge sharing, vision creation, and stakeholder empowerment that occurs in the process of developing the scenarios (Wollenberg et al. 2000, van den Belt 2004, Lebel et al. 2005). The diversity of stakeholders engaged in scenario development at finer scales tends to be greater than at larger scales (Renn et al. 1995, Lebel et al. 2005), and stakeholders typically include people such as government officials, private business owners, and local resource users such as farmers or fishers (Evans et al. 2006). These stakeholders often have very different levels of education, socioeconomic status, and beliefs and values, which pose particular challenges for communication.

The global vs. local scale differences outlined above reflect broad trends in the scenario exercises conducted to date. Multiple exceptions exist, and the fact that scenarios have been done in these ways in the past does not necessarily mean that they should or will be conducted in this way in future. There are a number of strongly quantitative local-scale scenario exercises (e.g., Erasmus et al. 2002, de Nijs et al. 2004), and some larger-scale exercises that have focused on stakeholder participation (e.g., Hisschemöller and Mol 2002, van de Kerkhof and Wieczorek 2005). The lack of a quantitative aspect in many local-scale scenario exercises, particularly in developing countries, may reflect resource constraints or a lack of expertise rather than an explicit desire to exclude quantification. Similarly, lower levels of stakeholder involvement at larger scales may occur because diverse participation is more difficult or costly at these scales (Rotmans et al. 2000, Kok et al. 2007). National- and regional-scale scenario processes are similar to global scenarios in terms of methods and challenges, but enjoy a level of coherence and focus among stakeholders similar to that found at local scales (e. g., Bohensky et al. 2006). A number of studies have shown that there is a mismatch between scientific models and policy needs (e.g., van Daalen et al. 1998), and between ordinary citizens and politicians (e.g., MNP 2004, van den Belt 2004). Integrating the methods that tend to characterize local- and global-scale scenarios may partially address these mismatches.

Several further scale-related aspects emerge from our consideration of scenario studies at various scales:

- Scenarios covering a wide spatial extent, such as a continent or the globe, tend to have a coarser grain or level of detail and cover a longer time period into the future than those covering a smaller extent, such as a nation or county. For example, the MA global scenarios ran to 2050, and many drivers and outputs were resolved only to the level of broad world regions such as the OECD or sub-Saharan Africa (Carpenter et al. 2005). The MA subglobal scenarios typically ran only to between 2015 and 2030 and used more detailed data (Lebel et al. 2005). One reason that multiscale scenarios are powerful is that such differences make it possible to investigate different processes at different scales or with different degrees of resolution. It should be noted, however, that advances in computing capabilities and high-resolution global data sets now allow for similar resolution in studies with widely differing spatial extents. Furthermore, differences in the objectives of scenario exercises, as well as data access and technical capacity constraints, mean that small-scale scenario exercises may sometimes have a coarser resolution than exercises that cover a wider area (e.g., Biggs et al. 2004).

- The degree of control that stakeholders have over the driving forces of change in a system is often related to the scale of the exercise. Important driving forces of change in local-scale social-ecological systems are often outside the control of the stakeholders. For example, market access for commercial crops is largely determined by international trade agreements and infrastructure development initiatives at the provincial/state or national level. Under these circumstances, participatory scenarios can help managers better understand the larger-scale forces affecting their communities. These scenarios also improve adaptive capacity by building understanding and trust and by anticipating and responding to change. This approach has been used by the Center for International Forestry Research to improve the adaptiveness of community forestry management in Indonesia and Madagascar (Wollenberg et al. 2000). At the national scale, there is often a greater degree of control over important driving forces, which may partly explain the success of scenario exercises at these scales in influencing political change in particular, for example, in South Africa (Galer 2004*a*,*b*) and Colombia (Kahane 1998, 2004). At the global scale, the focus shifts to driving forces that are shaped by the most powerful nations and/or international agreements. For example, the degree of global political and economic integration was a major axis of uncertainty in both the MA and IPCC scenarios (Nakišenoviš et al. 2000, Carpenter et al. 2005) and can be considered partly controllable at this scale.

- The methods used to communicate with stakeholders tend to vary between scales. Work at finer scales, especially in developing countries, usually takes place within community-based or grass-roots organizations, and the stakeholders often include people with varying levels of education and experience. In these cases, theatrical or other creative visual representations are often used to both develop and communicate scenarios across diverse groups, for example, in the Southern African MA scenarios (Biggs et al. 2004) and the Wisconsin northern lakes scenarios (Peterson et al. 2003*a*). Although these methods are not often used at regional or global scales, they could possibly be very effective at those scales. Scientists are generally not highly skilled at communicating to a broader public, so scenario exercises often benefit from interdisciplinary collaboration with actors, writers, or historians. Methods of stakeholder engagement at broader scales tend to center on formal dialog processes (e.g., de Solórzano 2004), detailed presentations, reports, and advertisements in newspapers, and are geared toward the more specialized and highly educated stakeholders who operate in international and policy contexts.

The effectiveness of these methods at finer scales depends on literacy and education levels as well as the ability of the scenario developers to convey information.

LINKING BETWEEN SCALES

Formal approaches for linking scenarios across multiple scales are not yet well developed or tested. In this section we draw on our experience and interpretations of the limited number of multiscale scenario exercises conducted to date to synthesize and suggest possible methods for linking between scales. Our hope is that these will be further developed and tested in future multiscale scenario exercises.

Two features can be used to categorize and understand types of multiscale scenarios: (1) the number of focal scales, i.e., the number of scales at which scenarios are developed, and (2) the connectedness between scales, i.e., the strength of the links between them (Zermoglio et al. 2005). Based on this categorization, we identify three types of scenario exercises from the case studies we examined: (1) single-scale scenario exercises, which are constructed at a single focal scale; (2) loosely linked scenarios constructed at two or more scales; and (3) cross-scale scenarios that are tightly coupled across two or more scales (Table 2).

Based on the studies we have examined, links between scenarios at different scales can be established up front, maintained iteratively throughout the exercise, or established after the different scenarios have been developed. In the case of tightly coupled cross-scale scenarios, links are usually established up front and reinforced by an iterative process of downscaling and upscaling. Downscaling refers to the “translation” of broader-scale scenarios to finer-scale situations, and upscaling refers to the reverse. An iterative process is generally necessary to incorporate feedbacks and maintain storyline consistency. With a few notable exceptions (e.g., Rotmans et al. 2000, 2005), most tightly coupled multiscale scenario exercises have been primarily top down, with greater emphasis on downscaling than on upscaling. This is probably because of the difficulties of incorporating diverse and inconsistent elements from smaller scales into the larger-scale storylines. It may also be because of the greater emphasis of the policy-making and research community on how top-down institutional and economic drivers affect regions and localities, rather than the effect of bottom-up factors.

In the case of loosely linked multiscale scenarios, links may be established up front or after scenario development. Linking up front is done by, for example, downscaling global storylines to create the boundary conditions for regional- and national-scale scenarios. Such downscaling can be done with varying degrees of flexibility. Quantitative scaling is often less flexible than qualitative scaling. For instance, the water budgets of all African nations need to add up to the continental budget, whereas qualitative downscaling of a storyline such as the MA “Techno Garden” leaves much room for defining the type and level of technological innovation and adoption in a particular region. When independent scenarios are developed at each scale, usually within a common overarching framework, and linked afterwards, this is typically done by categorizing the drivers and outcomes in the different scenarios and grouping similar scenarios at different scales. This is the approach that was adopted in the Southern African MA (Biggs et al. 2004, Kok et al. 2007).

Links between scales in the studies examined are of two broad types: either the process of developing the scenarios can be connected or the elements and outcomes of the scenarios can be linked (Zurek and Henrichs 2007). In both cases, the link between scenarios at different scales may be loose or tight. Linking the processes involves a range of approaches, from having the same team of scenario developers create the scenarios at each scale to running parallel processes in which scenarios are built using the same methods. Depending on the chosen process, consistency between the scenarios at the various scales differs. When linking the elements and outcomes of the scenarios is the chosen method, various linking options, ranging from a complete translation of focal questions, assumptions, drivers, and outcomes across the scales to sets of scenarios that merely address similar broad issues at different scales, have been used.

We have synthesized the following four methods of linking scenario elements and outcomes from case studies in the MA (Lebel et al. 2005) and the Global Environmental Change and Food Systems program (Ingram et al. 2005). Although we refer specifically

Table 2. We define three categories of scenarios: single-scale, loosely linked multiscale, and tightly coupled cross-scale. Each of these has specific advantages and disadvantages, and the type most suited to a particular scenario exercise will depend on the objectives of the exercise.

	Single scale	Multiscale	
		Loosely linked	Tightly coupled (cross-scale)
Number of focal scales	1	At least 2	At least 2
Consistency of storylines across scales	Not relevant	Storylines usually differ and are inconsistent across scales	Storylines have a high level of consistency across scales, and there is an explicit focus on downscaling and/or upscaling.
Consideration of drivers at other scales	Exogenous drivers from other scales included to the extent that they are relevant to the focal scale	Exogenous drivers and constraints from higher and lower scales are included in a similar way to single-scale scenarios. The set of scenarios is usually constructed within a common broad conceptual framework and will incorporate similar types of drivers at different scales.	Exogenous drivers and constraints from higher and lower scales are included via downscaling and upscaling procedures.
Consideration of feedbacks between scales	Not considered	May or may not be considered	Explicit linkages between scales and incorporation of feedbacks
Main advantages	Simple; no distraction by concerns at other scales	Allows stakeholders at each scale to frame the issues that are important to them from their specific perspective	Allows for consideration of feedbacks between scales and evaluation of how an issue plays out at different scales
Main disadvantages	Important feedbacks between scales may be missed or important externalities at other scales may be overlooked.	Scenario outcomes at different scales or different places are not directly comparable.	Very costly; may lose credibility because stakeholders at, especially, lower scales may not have much latitude to define the issues to be considered
Example	Mont Fleur Scenarios (Kahane 1992)	Southern African MA scenarios (Biggs et al. 2004)	MedAction scenarios (Kok et al. 2006*a*,*b*)

to global and regional scenarios, these methods may be used for any set of scales:

- Driver trajectories at the global scale are used as boundary conditions to frame developments within the regional-scale scenarios. The regional scenarios are developed in a way that ensures that the outcomes of the regional scenarios do not conflict with those of the global scenarios. An iterative process is often used whereby the global-scale storylines are reassessed and reworked in response to regional-scale outcomes. This approach may be used to develop loosely linked multiscale scenarios or tightly coupled cross-scale scenarios. The MedAction scenarios (Kok et al. 2006*a*,*b*) used an iterative approach to link local-level degradation scenarios to scenarios for the Mediterranean region in a tightly coupled cross-scale exercise (Kok et al. 2007). The Gariep Basin component of the Southern African MA used a noniterative loosely linked approach to translate a set of scenario archetypes (Scholes and Biggs 2004, Raskin et al. 2005) into basin-scale stories (Bohensky et al. 2006).

- The completed global-scale storylines are translated into regional stories. For example, scenarios for the agricultural future of Europe and the Netherlands (e.g., de Nijs et al. 2004, Rounsevell et al. 2006, Westhoek et al. 2006) have been developed in this way using the IPCC emissions scenarios (Nakišenoviš et al. 2000) as a starting point, and then modifying the scenarios to address region-specific uncertainties. The Portugal MA scenarios were similarly constructed using assumptions and decision-making paradigms from the MA global scenarios (Pereira et al. 2004), and the ongoing GEO scenario effort has also adopted this approach (Rothman 2006). In contrast to the previous method, some of the resulting scenario outcomes may conflict with those at the larger scale. This approach is common in developing loosely linked multiscale scenarios.

- Regional scenarios are developed with little or no reference to the global scenarios and then mapped onto the global scenarios. The mapping may be done by classifying the scenarios at each scale into several archetypes, based on their drivers and outcomes. The Southern African MA and Caribbean Sea MA scenarios were linked in this way to the MA global scenarios (Lebel et al. 2005). This approach is particularly effective if engaging stakeholders and maintaining credibility at multiple scales is a key focus of the scenario development process. The disadvantage is that the scenario storylines will contain a substantial degree of inconsistency, and cross-scale processes and feedbacks are not well accounted for.

- Global scenarios are used to test the viability and effectiveness of regional policy options without developing complete regional scenarios. This allows exploration of, for example, which policy options would be the most effective or robust in alternative future worlds.

Scenario exercises that aim to promote dialog between stakeholders at different scales are particularly challenging. The logistics are complex, and participatory scenario exercises consume significant resources, with costs rising as the network of stakeholders involved broadens. The benefits are an increased appreciation of perspectives from other scales, and a greater consideration of cross-scale processes and trade-offs between scales. To achieve such cross-scale participation, one needs to consider how scenarios at a particular scale can include stakeholders from other scales, either as observers or participants within the exercises themselves to help shape the focal questions or as an audience for the outputs. Based on our experience and the case studies examined, we suggest that, to promote understanding across different scales, representatives from, for example, the global-scale scenario team could participate in the regional- or local-level scenario exercises, at least as observers, and local- or regional-level representatives could participate in the global-level exercises. Stakeholders who function across multiple scales, such as a researcher with a personal interest in a local area or a high-level politician concerned about a certain village, can be particularly useful in this role.

If the goal of the scenario exercise is to clarify the values, needs, and wants of stakeholders at several scales, it may be beneficial to bring the full scenario teams from each scale together on several occasions during the process. This would allow each team to be exposed to and comment on the scenarios being developed at other scales and to receive comments from the other groups in turn. However, this can be very challenging if there are large differences in education levels or cultures between the different groups. Because of differing world views that often exist at different scales, fully coupled cross-scale scenarios might therefore best be used only to link scales with similar levels of understanding and application. The GEO-4 scenarios (UNEP 2006), designed to assess the health of the global environment and identify and respond to developing environmental trends, are a good example. Rather than attempting to link global scenarios to local village-scale scenarios, they aim only to link global-level and regional-level, i.e., subcontinental to continental, scenarios. Although global scientists and regional representatives from universities, NGOs, and government agencies were able to find common ground during scenario construction, local farmers and global scientists, for example, may have had more difficulty.

CHOOSING AN APPROPRIATE DEGREE OF LINKAGE

Deciding whether to link scenarios across scales and choosing the appropriate degree of linkage depends on the primary goal of the scenario exercise and the resources available. Single-scale and multiscale scenarios both have advantages and disadvantages. The obvious disadvantage of single-scale scenarios is that important drivers and constraints operating at other scales, as well as feedbacks and alternative perspectives from other scales, may be missed. The advantages of single-scale scenarios are that they may enhance stakeholder engagement at that scale and avoid or reduce the complexity and high costs associated with developing multiscale scenarios.

The advantage of multiscale scenarios are that they can, at least to some extent, take account of cross-scale feedbacks and differences in drivers and stakeholder perspectives at different scales. Based on our assessment of multiscale scenarios, we suggest that, if the aim is to engage stakeholders, loosely linked scenarios are generally more appropriate. Loosely linked multiscale scenarios tend to allow more freedom to explore the issues of concern to the stakeholders at each scale. In this case, any of the linking options identified above may serve as a bridging mechanism between stakeholders at different scales to understand the impact of decisions made at one scale on other scales. A major disadvantage of loosely linked scenarios is that the storylines are often inconsistent across scales and cross-scale interactions are not well accounted for. Tightly coupled cross-scale scenario exercises are more appropriate when the aim is to evaluate cross-scale processes and potential responses. We therefore suggest that tightly coupled cross-scale scenarios are most appropriate if the main objective is to further scientific understanding or to inform policy making with respect to an issue that has differential effects at different scales or has strong cross-scale interactions or feedbacks. Such fully coupled scenarios can include processes and perspectives necessary to allow an in-depth cross-scale analysis and the development of cross-scale institutional links. However, developing tightly coupled cross-scale scenarios requires a very large input of time, technical expertise, and financial resources, which should not be underestimated.

Several further practical and conceptual challenges should be considered when deciding on the approach to adopt in a particular assessment. Drawing on the limited number of multiscale scenario exercises conducted to date, we suggest that the following are important issues to note:

- *Different goals and methods at different scales may lead to incomparable results.* Because scenario design is often guided by the rule “form follows function,” a multiscale scenario exercise faces the challenge that scenarios at each scale often have different functions or goals and hence use different methods and processes. In the exercises carried out to date, global-scale scenarios have tended to be more science- or research-oriented and rely heavily on quantitative methods, whereas local-scale scenarios have often been more stakeholder-oriented with greater use of qualitative methods. On the one hand, such differences in goals and methods make multiscale scenarios powerful, in that they broaden the perspectives adopted and the issues addressed. On the other hand, these differences can lead to scenario results that are not easily integrated or compared, at least in a stricter quantitative sense. At any scale, it is crucial to define the goals of the scenario exercise as clearly as possible to avoid confusion among participants and stakeholders.

- *Linking is difficult when the relevance of issues and processes changes with scale.* Some issues and processes are scale-specific and lose meaning when transferred to other scales. In many local-scale scenario exercises, scenario developers report difficulties with upscaling or accounting for important local processes or issues in global-scale scenarios (Lebel et al. 2005). For example, local factors that contribute to collective action, such as social capital, networks, and knowledge, may be difficult to account for in global scenarios. Local knowledge is also sometimes seen as irrelevant or unreliable at broader scales or discarded because of the complexities and time constraints faced in integrating very different types of knowledge (Erickson et al. 2005). In the case of downscaling, certain elements of global scenarios may become less relevant at subglobal scales. For instance, the rapid rise in green technology in the MA “Techno Garden” scenario (Carpenter et al. 2005) seems of little importance, or at least much less important than other factors, when considering the future of some parts of the developing world (Bohensky et al. 2006, Kok et al. 2007). Scenario developers or stakeholders may be reluctant to include processes or issues that are important at other scales but which they feel do not directly affect them. For example, some of the subglobal assessments of the MA chose not to use the MA global scenarios because they felt that the importance of local issues outweighed those stressed in the global scenarios (Lebel et al. 2005, Kok et al. 2007).

- *Credibility is often sacrificed at one scale or another.* Multiscale scenarios must often sacrifice either local specificity or global significance. Trade-offs frequently exist between scenario credibility to users at different scales. Large-scale studies are often eager to use smaller-scale studies to ground-truth or verify their findings. However, excessive encouragement to incorporate global issues such as climate change and global trade regulations in local scenarios may result in a “hi-jacking” of local-scale scenarios with broader-scale issues and the neglect of important local-scale concerns and uncertainties. The outcome is often a loss of scenario ownership and credibility by stakeholders at the local level. The reverse is also possible, i.e., hi-jacking global scenarios with issues important only to certain places, although there is less evidence of this in the multiscale exercises conducted to date. It may, however, play a role to the extent that the global scenario exercises tend to be dominated by scientists, mostly from developed countries, owing to their greater level of technical expertise and funding. Those who initiate the scenario process influence who becomes engaged and may encourage or discourage certain groups from participating or particular threads of discussion from being pursued. The issues considered most important in global scenarios may therefore be somewhat biased toward the interests of scientists and the concerns of developed countries and framed from their perspectives. For example, a change in values and attitudes toward the environment was a major axis of uncertainty in both the MA and IPCC scenarios. In many developing countries, this is seen as substantially less important to future environmental conditions than the ability of governments to develop and implement policies and regulations (Biggs et al. 2004, Lebel et al. 2005).

IS LINKING SCENARIOS ACROSS SCALES WORTHWHILE?

The central conclusion emerging from this dialog is the need for future multiscale scenario exercises to critically evaluate the reasons for linking across scales and the expectations associated with doing so. Multiscale environmental scenarios clearly have significant advantages over single-scale exercises when it comes to broadening the perspectives, processes, and issues addressed. However, in many cases it may not be desirable to tightly link scenarios across scales. Inappropriate attempts to link between scales may have unintended and undesirable consequences, mainly by alienating stakeholders at one or more scales. For example, concern arose that local stakeholders in Mozambique would react negatively to the “New Partnership for Africa’s Development” scenario used at the scale of the broader Southern African region (Scholes and Biggs 2004), because it represented a policy process in which they felt marginalized (T. Lynam, *personal communication*). This was an important reason for abandoning the original intention of developing tightly coupled cross-scale scenarios in this exercise (Kok et al. 2007). On the other hand, if important cross-scale processes are at play, ignoring these can result in the recommendation of ineffective or even damaging responses, and an opportunity may be missed to account for cross-scale constraints and to develop effective cross-scale institutions. However, it may not be possible to achieve high levels of stakeholder ownership in tightly coupled cross-scale exercises if they are not preceded or accompanied by a process that allows stakeholders to express their concerns from their perspectives.

For multiscale scenarios dealing with the management of social-ecological systems, the best links in general may be loose links. Loosely linked scenarios that share a common framework, e.g., the Millennium Ecosystem Assessment (MA), or common focal issue, but are developed independently at each scale based on scale-specific stakeholder input, are typically better able to maintain credibility and relevance to users by retaining a greater degree of specificity. Loosely linked multiscale scenarios still allow for some investigation of cross-scale processes and require more modest levels of resources and a more manageable stakeholder engagement process than fully linked cross-scale scenarios. Importantly, loosely linked scenarios may help reflect and communicate different points of view across scales. In some cases, such an approach may even allow convergence of issues and viewpoints to emerge rather than forcing it, serving to enhance the robustness of the findings and the success of the overall exercise. Two good examples are the multiscale Southern African MA scenarios, in which governance was independently identified as a major uncertainty at all scales (Biggs et al. 2004, Kok et al. 2007), and the VISIONS project, which developed scenarios for the European and local scales. Although the same group of scientists facilitated the entire VISIONS process and aimed for consistency across scales, local scenarios were developed independently and subsequently combined with those at the European level to form a set of "Integrated Visions for a Sustainable Europe" (Rotmans et al. 2000, 2005). Loosely linked multiscale scenarios can also facilitate the identification of complementary or integrated responses across scales. For example, the local participatory scenarios of the Alternatives to Slash-and-Burn Programme in Thailand led to storylines similar to those constructed in broader-scale research-driven "expert" scenarios, but the response options identified differed markedly (P. Thongbai, D. Pipattwattanakul, P. Preechapanya, and K. Manassrisuksi, *unpublished manuscript*). Local decision makers focused primarily on endogenous, local-scale driving forces, whereas broader-scale decision makers focused on drivers that were exogenous to the communities concerned. Integration of the outcomes of the two exercises is likely to provide a more effective set of response options than either exercise could do on its own.

Finally, our attempts to understand the methods that have been used to link scenarios at different scales, and more importantly, the reasons for choosing specific methods, underscore the importance of documenting these details. The written documentation from many scenario studies focuses on the scenario outcomes, modeling methods, and methods used to engage stakeholders. Information on the processes used to select particular methods, the reasons why these methods were chosen, and how they may have influenced the scenario outcomes is usually not documented. Better documentation of these aspects will enhance our ability to carry out comparative studies and increase our potential for understanding, developing, and testing methods of linking scenarios across scales.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/vol12/iss1/art17/responses/

Acknowledgments:

Garry Peterson, Elena Bennett, and Steve Carpenter provided the initial idea for the dialog. We thank Sandra Velarde, Steve Carpenter, Holly Gibbs, and Tim Holland for their helpful comments on the draft manuscript. The subject editor (Elena Bennett) and two reviewers are thanked for their guidance in revising the manuscript. Reinette Biggs and Ciara Raudsepp-Hearne jointly led and coordinated the dialog. All authors contributed to the online dialog and the drafting of the paper.

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