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Synthesis, part of a Special Feature on Strengthening adaptive capacity

Foghorns to the Future: Using Knowledge and Transdisciplinarity to Navigate Complex Systems

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ABSTRACT. Complex systems are shaped by cross-scale interactions, nonlinear feedbacks, and uncertainty, among other factors. Transdisciplinary approaches that combine participatory and conventional methods and democratize knowledge to enable diverse inputs, including those from local, informal experts, are essential tools in understanding such systems. The metaphor of a “bridge” to overcome the divide between different disciplines and knowledge systems is often used to advocate for more inclusive approaches. However, there is a shortage of information and consensus on the process, methodologies, and techniques that are appropriate to achieve this. This paper compares two case studies from Peru and South Africa in which community-level assessments were conducted as part of the Millennium Ecosystem Assessment, and explores the different conceptual models used to deal with scale and complexity, the methods adopted to deal with epistemology, and the different means of dealing with uncertainty in each assessment. The paper highlights the conceptual and practical challenges encountered by each assessment and discusses some of the conceptual and practical trade-offs involved in the selection of particular approaches. We argue that a boat navigating between unknown shores may be a more appropriate metaphor than a bridge, whose starting and end points are fixed and known.

Key Words: *ecological assessment; community-based assessment; complexity; scale; epistemology; methodology; Millennium Ecosystem Assessment; complex systems; uncertainty; Peru; South Africa; case studies; transdisciplinary research*

INTRODUCTION

Understanding the relationship between people and the environment requires that researchers on the ground simultaneously navigate multiple world views (Gadgil et al. 2003) and complex social-ecological systems (Scheffer et al. 2001, Berkes et al. 2003) characterized by cross-scale interactions, nonlinear feedback, and uncertainty (Gunderson and Holling 2002). Transdisciplinarity is often touted as the answer to the difficulties involved in understanding such systems. The metaphor of a “bridge” is frequently used to typify the crossing of these disciplinary and knowledge divides, and this concept is often reflected in conference and publication titles, e.g., Gunderson et al. (1995), a Society for Economic Botanists conference held in Hawaii in 2001 (http://www.atbio.org), and a more recent Millennium Ecosystem Assessment conference held in Egypt in 2004 (http://www.maweb.org).

There is, however, a lack of guidance and experience in adopting integrated approaches involving different world views, and few academic curricula address these challenges. In reality, this type of complex systems research allows for different conceptual and practical approaches, which can be confusing and disconcerting to researchers. The recent Millennium Ecosystem Assessment (MA) illustrated this point poignantly, as the papers submitted to the MA conference in Egypt bore testament. This paper is intended to go some way toward dispelling the confusion so common in this type of research, at least in community-level studies. By comparing two case studies from Peru and South Africa, where

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community-level assessments were conducted as part of the MA, this paper explores the different conceptual models used to deal with scale and complexity, the different methods adopted to deal with epistemology, and the different means of dealing with uncertainty in each study.

In so doing, the paper highlights the conceptual and practical challenges encountered by each assessment, and the ways in which each team dealt with those challenges. Throughout, the emphasis is on the multiple pathways that present themselves in complex systems research, and the added challenge posed by the need to compare findings. The final section uses the two case studies to highlight some of the conceptual and practical trade-offs involved in the selection of particular approaches. We argue that the "bridge" metaphor might be too rigid and predetermined for this poorly defined terrain; this paper is intended to serve as a foghorn amid the confusion that calls for integrated studies of complex systems can create on the ground.

The variable theoretical landscape of complex systems

It is useful at the outset to outline what is meant by complex systems research and some of the major factors that may lead to confusion. Theories about the relationship between people and the environment influence the ways in which natural resource management is understood and applied (Janssen 2002). Whereas early theories relied heavily on a dichotomy between people and the environment (Malthus 1798, Meadows et al. 1972), more inclusive approaches emphasizing systems thinking and human adaptation to environmental and social processes have gained currency during the past century. This has brought with it principles and ideas that emphasize complex system dynamics (Kay et al. 1999), linked social-ecological systems (Berkes and Folke 1998), nonlinear feedback at multiple scales (Gunderson and Holling 2002), and resilience to change in social and ecological systems (Holling 1986).

Ecosystem assessments such as the MA compel researchers to deal with complex system dynamics, including but not restricted to nonlinear processes, uncertainty, emergence, cross-scale interactions, self-organization, novelty, slow- and fast-changing variables, and a nested hierarchical structure (Walker and Abel 2002, Berkes et al. 2003, du Toit et al. 2004). Both natural and human systems exhibit characteristics of complex systems, and linked social and ecological systems are increasingly considered to be self-organizing, with a loose hierarchical structure (Gunderson and Holling 2002) and various emergent processes. They are furthermore subject to relatively sudden reconfigurations from one state to another (Scheffer et al. 2001). Natural resource managers and systems researchers face enormous challenges when confronting this complexity in their work (Walker et al. 2002).

Many fields of research have contributed to the recognition of complex system dynamics in both human and natural systems, which led to some confusion and much debate within and between the MA assessment teams during working group meetings. Some of this confusion resulted from the varying emphases placed on the dynamics involved. For example, although general systems theory argues for an emphasis on connectedness, context, and feedback (von Bertalanffy 1968), chaos and complexity theory highlights the recognition of self-organizing behaviors in social and ecological systems (Casti 1994, Kay et al. 1999). Evolutionary theorists, on the other hand, might argue for an emphasis on feedback to avoid simple dichotomies between human and natural systems (Wicken 1987, Adger 1999), whereas historical ecologists emphasize history (Balee 1998), and postnormal scientists call for an emphasis on uncertainty and methods to ensure the validity of conclusions in inherently complex systems (Functowicz and Ravetz 1990).

Therefore, researchers who take on the challenge of a complex systems approach with Quixotean zeal may quickly become confused and frustrated by the many directions in which their analyses are pulled. This confusion arises not only from the existence of various approaches and understandings between disciplines but also from attempts to communicate findings between assessments and individuals when different approaches have been used. The resulting challenges are discussed later in this paper. There are two other major factors that cause confusion in complex systems research: scale and epistemology.

Scale

Scale refers to the spatial, temporal, quantitative, or analytical dimensions used by scientists to study objects and processes (O'Neil and King 1998, Gibson et al. 2000). Ecological and social systems tend to organize into strongly interacting clusters of processes operating at similar spatial or temporal scales (Allen and Holling 2002). Consequently, an understanding of how a selected scale of analysis may influence the patterns observed, and therefore inferences regarding causality, is essential in understanding interactions between human and natural systems (Gibson et al. 2000, Munda 2000).

However, despite recent comprehensive reviews of scale (see, for example, Schulze 2000), the disparate treatment that scale has received from the various disciplines makes it one of the most fundamental methodological challenges confronting researchers. For example, whereas systems ecologists might argue that scale is an explicit consideration when assessing any system (Levin 1992), geographers would place the emphasis on spatial scale (Wood and Lakshmi 1993), historical ecologists on temporal scale (Balee 1998), economists on emergent features (Martónez-Alier and Schlupmann 1991), sociologists on interactions between scales (Coleman 1990, Scheffer et al. 2002), and political scientists on institutional and conceptual aspects of scale (Ostrom and Hess 2000). This makes for an inconsistent theoretical landscape for researchers who seek to become transdisciplinary in their endeavor to come to terms with scale in complex social-ecological systems.

Concomitantly, community-based assessments inevitably involve peer review by local communities, making the process even more complicated. Researchers thus, sometimes unknowingly, enter the equally varied theoretical landscape of epistemology while still grappling with scale and complexity.

Epistemology

Epistemology is the philosophy of knowledge. More specifically, it is a field of research that seeks to come to terms with what we can know, and the status of knowledge about a particular reality (Jones 2002). There is much disagreement about whether or not reality can be divorced from social experience, and therefore whether it can be objectively accessed by a particular knowledge system (Jones 2002). For this reason, debates about knowledge are often centered on power (Healy 2003), because logically the system of knowledge that is recognized as being able to tap into the "objective reality" holds greater sway than other knowledge systems. This has lead to tension about the validity of science vs. that of informal, sometimes also referred to as "local," knowledge.

There are various approaches and rationales both for and against the integration of scientific knowledge and informal or traditional knowledge in natural resource management. Whereas some, such as the social constructivists, argue from ontological perspectives (Milton 1996, Macnaghten and Urry 1998, Jones 2002), others argue from ethical and even management standpoints (Gadgil et al. 2000, Berkes et al. 2003). Still others reject the very idea of integration and argue that communicating between knowledge systems may lead to further marginalization of the nondominant knowledge systems concerned (Latour 1987, Nadasdy 1999, du Toit 2004).

However, community-level projects are already underway worldwide (Barrett et al. 2001, Chakraborty 2001, Shackleton and Campbell 2001), and therefore knowledge systems are coming to heads, regardless of the arguments behind these varied perspectives. For this reason, methods and approaches need to be found to conduct community-level research and assessments that pay attention to the challenges outlined in this section. Comparative local-level case studies are a step in this direction.

CASE STUDIES FROM SOUTH AFRICA AND PERU: MULTIPLE PATHWAYS

Different navigational tools such as conceptual models, methods, and techniques were used in local-level assessments conducted in Peru and South Africa under the Millennium Ecosystem Assessment (MA) initiative (Millennium Ecosystem Assessment 2003; http://www.maweb.org/). The Peruvian case study aimed to test and adjust tools and methodologies for the Vilcanota Millennium Ecosystem Assessment, which was still under way at the time of writing. The South African case represents work conducted in 2003 as part of the Southern African Millennium Assessment. In this section, we highlight the trade-offs that had to be made when researchers endeavored to study human-ecosystem interactions in the current theoretical landscape of complex systems. The MA case studies were similar in terms of the conceptual frameworks used, the involvement of local people, and the incorporation of informal knowledge in information gathering. In all case studies, there was a direct connection between local people and ecosystem services: all the communities needed ecosystem services in their everyday lives. However, they differed widely in terms of their ecological, tenural, and livelihoods profiles (Table 1).

Both the South African and Peruvian case studies sought to answer the overarching question posed by the global-level assessment (Millennium Ecosystem Assessment 2003): what are the current conditions and trends of ecosystems and the associated implications for human well-being? To answer this, the South African and Peruvian studies branched off in different directions (Table 2), paying testament to the multiple paths available in complex systems research.

Dealing simultaneously with scale and complexity

As indicated in Table 2, both the Peruvian and South African studies used the MA framework as a conceptual guide (Millennium Ecosystem Assessment 2003). The MA framework assumes a dynamic relationship between people and ecosystems. Human and ecological systems are seen as interconnected, with ecosystem change affecting human well-being and vice versa. The framework assumes that the relationship between ecosystems and human well-being cannot be understood without a consideration of multiple spatial and temporal scales; it also recognizes cross-scale interactions. The mismatch between the scale of ecosystem processes and the scale of decision making is considered to be a key reason for many environmental problems. The model also introduces the ethical problems encountered by researchers who conduct local-level investigations into these kinds of linkages, and acknowledges that different knowledge systems may be more important when dealing with different scales of analysis. However, the MA framework alone does not do justice to the dynamism of the interactions between human and natural systems at the local level (Millennium Ecosystem Assessment 2003).

To overcome this shortfall in the framework, the South African local-level assessments used the adaptive renewal or “panarchy” model (Holling 1986, Berkes and Folke 1998, Gunderson and Holling 2002) as a conceptual guide to deal with scale and complexity simultaneously and to address the shortcomings of the MA framework for local-level purposes. This model integrates the ideas (1) of fast- and slow-moving emergent features of complex systems, borrowed from ecological economics; (2) of temporal scale, borrowed from geography and environmental history; (3) of vertical scale, borrowed from the political sciences; and (4) that micro-level phenomena affect macro-level processes just as much as the macro affects the local, borrowed from sociology (Coleman 1990).

The premise of the model is that both natural and human systems undergo cycles of organization, collapse, and renewal. The adaptive renewal cycle emerged from earlier discussions around multiple stable states (Holling 1973) and incorporates key processes underpinning resilience (Walker et al. 2002), institutional memory (Berkes and Folke 2002), disturbance (Gunderson 1999), adaptation, and novelty (Berkes et al. 2003). Thus, the model provides a useful navigational tool (Berkes et al. 2003) for conceptualizing and assessing the self-organizing characteristics of complex adaptive systems (Kay et al. 1999), historical processes (Balee 1998), context and feedback (von Bertalanffy 1968), and the evolutionary link between institutions, culture, resources, and the physical environment (Adger 1999). The model also acknowledges the adaptive capabilities of local communities and ecosystems, an aspect significantly lacking in the MA framework.

In the Peruvian case study, the challenge was to incorporate the traditional Andean cosmology framework and principles (TACFP) and use them alongside the MA framework so that the assessment could be based essentially on indigenous understandings of ecosystem change. Complex adaptive hierarchical system (CAHS) theory (Allen and Starr 1982, Lowrance et al. 1986, Giampietro 1994) was used as a starting point to assess the feasibility of using TACFP to assess multiscale processes. CAHS theory has three discerning characteristics:

1. *Hierarchy as a system of filters.* Society and its rules act as a system of constraints that buffers the intensity and frequency of changes in ecosystems.

2. *Holons and the dual nature of hierarchical systems.* A component of the hierarchy, the holon consists of smaller parts that are lower in the hierarchy. It maintains its own integrity

Table 1. Case study profiles: South Africa and Peru.

Case study	Land tenure	Livelihoods	Relationship with natural resources	Biome/vegetation type
South Africa, Eastern Cape Province. Community names: Qongqota and Machibi (27° 28' E, 33° 00' S)	Communal, most have been subjected to resettlement at some point in the past	Animal husbandry is very important, arable field cultivation is on the decline, most families keep home gardens. Other sources of income include collection of wild resources, state pensions and welfare grants, migrant labor.	isiXhosa identity is strongly founded on interaction with ancestors. There are strong links between the spiritual world and environmental features such as pools, intact forests, medicinal plants and ancestors' graves. This relationship has become increasingly strained through interaction in the formal economy and associated land-use change.	Valley Bushveld/ xeric Succulent thicket
South Africa, Richtersveld National Park (28º15' S, 17º 10' E)	Communal tenure, those who live outside the National Park hold a 30-yr lease allowing access for grazing. The original inhabitants remain inside the park.	Seminomadic pastoralists (mainly goats and sheep); other sources of income include collection of wild resources, state pensions and welfare grants, employment in local mines, migrant labor.	Fuel wood is the primary energy source. Bushmeat, fish, and wild fruits supplement diets. Natural streams and watering points are central to all pastoralist activities.	Succulent Karroo
Peru, South Andean Mountain Chain, Cusco region. Community names: Sacaca, Amaru, Paru-Paru, Cuyo Grande, Chawaytiri, and Pampallaqta (between 13º30' E, 70°31' S and 14º20' E, 71°21' S)	Communal after agrarian reform in the 1960s	Polyagriculture at household, community, and landscape levels; animal husbandry; collection of wild resources; barter interchanges; handicrafts and fabrics; migrant labor	Close relationship with natural resources through traditional Andean cosmology, which links natural resources, processes, and services with spiritual beliefs and human landscape management and local practices	Mountain ecosystems, high diversity of ecological conditions following an altitudinal pattern. Puna, Suni, and Yunga biocultural zones.

while simultaneously supporting the other parts of the whole, on which it depends for its existence.

3. *Arbitrariness.* Investigators can arbitrarily select a particular window of observation to isolate, describe, and simplify a part of a system as an independent entity. In assessing a social-ecological system and predicting its future, this model advocates that investigators select the windows of observation carefully and ethically, recognizing their limitations.

TACFP has many similarities to CAHS. TACFP identifies the existence of three main hierarchical systems containing all of the ecological, social, and cultural processes of life. These systems are *Kaypacha* or the real world, *HananPacha* or the world of sacred features and divinities, and *UkuPacha*, the world of dead people or ancestors (Milla 1983). Each of these worlds could be seen as a holon of the whole system made of smaller components at lower hierarchical scales. Traditional space management principles were widely studied by anthropologists in the 1970s (Mayer and de la Cadena 1989, Murra 1975). These principles, which include reciprocity, complementarity, and diversification, take place and are implemented by each social unit, i.e., person, household, community, ethnic group, region, at each scale. These cultural conceptions of

Table 2. Summary table of approaches followed by the South African and Peruvian case studies. MA stands for Millennium Ecosystem Assessment, PRA for participatory rural appraisal.

Case study	Conceptual models used to deal with scale and complexity	Methods for bridging epistemologies	Approaches for dealing with uncertainty
South Africa	MA framework Adaptive renewal Nested institutional and ecosystem change	Summaries of literature Forum theatre PRA workshops Combination of local and GIS mapping Vegetation surveys Water quality testing Household surveys Key informant interviews	Triangulation through: Historical records Review of existing literature Combination of various qualitative and quantitative methods Community validation of scientific knowledge Community validation of its own knowledge through feedback meetings Scientific validation of local knowledge through surveys and literature
Peru	Complex adaptive hierarchical systems Traditional Andean cosmology MA framework	Local debate and learning groups Video reports and registers Collective participative mapping Traditional geographical information system *Arariwas* (traditional citizens' juries) Traditional resources registers (potatoes and medicinal plants) Household surveys Conversations with local people with specialized knowledge Field trips and resources surveys	Acceptance of uncertainty and variability as inherent property of the Andean system and the research process Application of traditional space management principles to methodologies and tools Triangulation through: Review of existing literature Historical research Analysis and use of customary practices and norms Integration of traditional and occidental taxonomic systems for space and resources characterization Oral traditional registration of knowledge Combination of quantitative and qualitative information

space, processes, and endogenous principles constituted the roots of the assessment strategy in Peru.

Divergent methods for dealing with epistemology

Both the Peruvian and South African assessments sought explicitly to include different knowledge systems and world views in the assessment process. The reasons behind this were, however, different in the two cases. Whereas the South African local-level assessments came predominantly from the ecosystem management school (see, for example, Berkes et al. 2000, Gadgil et al. 2003), the Peruvian study emphasized the ontological and ethical aspects of systems assessments (see, for example, Callicot 1994, Milton 1996, Macnaghten and Urry 1998), highlighting the need to respect and empower informal and traditional knowledge and rights.

Conceptual models help researchers to navigate transdisciplinary research in complex systems, but local assessment practitioners require innovative methods and techniques if they hope to bridge epistemologies on the ground. The problem involves not only researchers communicating with and understanding informal knowledge, but also the additional difficulty of communicating the information thus received back to other scientists in a way that makes sense and does not further marginalize the less powerful informal knowledge system (Nadasdy 1999).

In the South African assessment, learning and memory were considered to occur and to be stored at the level of the group, i.e., a social constructivist approach, and therefore the techniques and methods used to bridge knowledge systems were consensus based. Realizing that the methods used during an investigation also have ethical implications (Munda 1999), researchers used a combination of participatory research techniques that incorporated a range of visual, verbal, and interactive techniques. These included forum theatre, focus group workshops, and interviews (Borrini-Feyerabend 1997), semistructured interviews with key informants (Pretty et al. 1995), and a range of participatory rural appraisal techniques (Chambers 1994, von Kotze 1998, Kapoor 2002).

These techniques aided considerably in communicating between knowledge systems at the village level but were less helpful in communicating findings back to decision makers. For this reason, and also to improve confidence in the data, qualitative findings were validated through more conventional methods such as household surveys, vegetation surveys, water quality testing, and histiography. Participatory mapping exercises were also conducted with the aid of geo-referenced orthographic photographs rather than free-hand mapping. The maps were then digitized, and land-use maps based on informal knowledge could thus be presented in a scientifically acceptable way.

A final aspect of the South African local-level assessments involved the dissemination of the combined informal and scientific knowledge back to the communities involved. This was achieved through scenarios (van der Heijden 1996, Peterson et al. 2003) or story lines representing a range of plausible futures. These scenarios were an interpretation of information already gathered at the local level, combined with national-level data on political and economic changes.

Scenarios were first developed at broader regional levels (Bohensky et al. 2004) and then interpreted by the researchers for the communities in question. These interpretations were based on the researchers' understanding of the local-level processes in each community. A development acting group who spoke the same language as the communities then turned these interpretations into simple story lines and later into dramas. These dramas were performed for the community and then amended through feedback from participants to demonstrate how broader economic and political changes might play out at the village level. Through a video documentary and written reports, this information was then presented to other scientists. Scenarios therefore provide just one example of how information generated at broader scales can be translated to local-level actors in a way that makes sense to them, and how local responses can be translated back to scientists working at coarser scales.

In Peru, on the other hand, the ethical component of complex systems research underlay the entire process, emphasizing the need to respect the local and traditional rights of the communities involved and to empower them. The inherent complexity of the system forced the assessment to select the most relevant services and processes to be assessed. For whom these services and processes were relevant was the key question in this task. Therefore, local people identified the processes and services to be assessed through debates in which scientific and traditional information was cross-checked. An overview committee was established with local authorities to control the entire process. Once the services and resources had been selected, methodologies and tools were designed and adapted with local technicians who were identified and legitimated by the local communal assemblies that constituted traditional governing institutions.

The Peruvian assessment dealt explicitly with a crucial question that arises from the issue of participation: who has the power to impose the research process? Within this question, are the questions of who decides on the key goals, methodologies, and tools to be applied and who identifies the stakeholders and social groups to participate? To deal with these questions, the Peruvian assessment treated local experts not simply as stakeholders who were asked to participate, but as leaders and specialized researchers with the right to raise relevant research issues and to suggest appropriate methodologies and tools.

The main research strategies used with local technicians included resource surveys, participatory mapping, local debates within learning groups, endogenous video reports, *arariwas* or traditional citizens' juries, traditional resources registers for priority resources such as potatoes and medicinal plants, household surveys, and in-depth interviews with people who had specialized knowledge about key resources. The information thus generated was shared and validated with the communities at two different levels: (1) learning groups composed of volunteers from all age and sex groups and (2) local communal assemblies that involved the entire community.

TRADE-OFFS INVOLVED IN A COMPLEX SYSTEMS APPROACH

The inadequacy of the literature dealing with research processes in complex systems research (Campbell 2002) means that researchers inevitably enter uncharted waters. Two key sets of trade-offs were identified in the Peruvian and South African assessments. The first set related to the advantages and disadvantages of selecting a particular set of conceptual models and research approaches. Although this provided a useful organizing framework for researchers working in different contexts, it necessarily influenced the questions asked, the selection of issues to be addressed, and the interpretation of results. The second set of trade-offs related to the advantages and disadvantages of democratized expertise, the confrontation of uncertainty, and the resultant dynamic and unpredictable nature of the research process.

Trade-offs in the selection of approaches and conceptual frameworks

In terms of research approaches, the three most important trade-offs were related to the following issues: (1) predesigned frameworks are convenient, but they eliminate alternative perspectives; (2) transdisciplinary assessments are inclusive and comprehensive, but their research outcomes are often superficial; and (3) predesigned questions make for more rigorous and comparable assessments, but they place constraints on reflexive learning processes. These trade-offs are discussed in greater detail below.

Predesigned frameworks vs. the loss of alternative perspectives

The South African case study incorporated informal knowledge, predominantly from a natural resource management perspective, as opposed to the ethical and ontological approach adopted by the Peruvian study. The latter approach proved very useful in identifying underlying causes of change, adaptive processes at the local level, and nonlinear relationships between processes and outcomes at different spatial and temporal scales. The use of these frameworks also improved the legitimacy and validity of the local assessments in the eyes of scientists and most policy makers. However, these models and relationships represented particular world views developed outside of the local context to identify processes deemed important by scientists. Therefore, the research team had to compromise between the use of local cosmologies to understand changing human-environment relationships and the a priori identification of issues relevant to scientists. The negative trade-off was that the process was less participatory than that advocated by the proponents of community-based natural resource management (Fabricius et al. 2004) and possibly, in the eyes of the local people, less legitimate than a true bottom-up assessment.

Inclusiveness vs. superficiality

Working across disciplines is indispensable when dealing with complex multiscale systems (Campbell et al. 2001). Local management systems and resource use patterns know no disciplinary boundaries, and the drivers of social-ecological systems are ecological, biophysical, geographical, climatological, historical, political, and economic. A transdisciplinary, inclusive approach allowed us to appreciate and record the many factors that influence such systems. The negative trade-off of this, however, was the sacrifice of a more detailed understanding of individual key processes. This trade-off was linked to the tight time frame that comes hand in hand with multiscale assessments such as the Millennium Ecosystem Assessment (MA). In the South African case study, researchers were involved in participatory research, ethnography, biological surveys, and historical analysis. Although this allowed for a broad and inclusive analysis of key processes and the linkages between them, it was impossible to attain an in-depth understanding of the respective processes in the time frame involved. Some of these processes, such as the relationship between diversity and productivity in natural and anthropogenic landscapes (e.g., Salmon 2000), the social and institutional impacts of large-scale economic interventions, and the effects of globalization, remain poorly understood but are probably critical to complex systems assessments.

Rigor vs. reflexive learning

Time constraints introduced some urgency into the assessment to ensure prompt and rigorous delivery of results, and this affected our ability to facilitate reflexive learning in participatory processes. The predesigned nature of the MA helped us to get our assessments off the ground rapidly. Although researchers were given a great deal of freedom in terms of their approach to the assessments as well as the techniques used, there was little time in the assessments for participatory learning. For example, when dealing with scenarios, the time constraints allowed only for community responses to the possible futures. No time was available to explore the community's own scenarios, to assess how feasible or appropriate the community responses were, or to evaluate responses to allow for critical thought. Although all of the methods were, to some degree, useful to both researchers and local participants, none of them promoted in-depth reflection as part of the assessment process.

Trade-offs in democratizing expertise

Participation vs. the ability to plan and predict

The Peruvian case study provides a useful example of trade-offs related to the inability of scientists to plan and predict community-based research processes. In line with the ethical considerations throughout the Peruvian research process, a great deal of control over the research questions and methods was devolved to local participants. The study therefore gained considerably by achieving desired levels of participation and thereby integrating indigenous cosmologies into the research process.

However, the devolution of control over research goals and processes raised the expectations of all the parties involved (see, for example, Fabricius et al. 2001) and hampered the ability of the scientists to plan the research process. During the Peruvian research process, three major expectations arose at the outset: (1) from the research team, expectations related to the relevance, content, and consistency of the final results; (2) from the local communities, expectations related to immediate short-term benefits; and (3) from politicians and authorities, expectations related to the legitimacy of their role, control, and power in the assessment process.

The researchers decided on the goals and methodology at the outset of the process. This is normal in scientific assessments, and even a prerequisite when dealing with externally funded research. Therefore, the researchers had certain expectations with regard to the results and their validity. However, despite the shared understanding among researchers of the sui generis nature of the work, uncompleted activities or information that was perceived to be less precise provoked fuzzy uncertainty and even distrust on the part of some researchers. For example, it led to questions about the influence of the facilitators, the methodologies applied, and even the usefulness of relying on informal knowledge. In the end, the frequency of the situation just described forced researchers to redefine the process itself so that the data could be validated in the scientific arena. Fortunately, the adaptive nature of their approach gave them the flexibility they needed to do this.

Expectations from the community related predominantly to the short-term benefits that would accrue to key individuals. Local participants expected to become more respected in their communities and to win socio-political power through their participation in the project because of the involvement of development-oriented institutions. As the assessment progressed, doubts emerged regarding the true interests of local participants. Some tried to satisfy personal interests, leading to local conflicts among local participants, between local participants and the rest of the community, and between the community and the research team.

A similar situation emerged with the politicians and governmental institutions involved. These participants entered the process with expectations about legitimizing their competencies and control at the local level. This led some of them to intervene in the assessment process, whereas others presented the process as their own. In both cases the aim was to maintain control over local processes. This represented a major trade-off in the Peruvian study. Expectations had to be confronted to achieve the desired levels of participation. Each group embarked on the assessment process with existing expectations, and the final outcome differed for every group. Therefore, the actual research process was only identifiable in hindsight, despite efforts by all parties to shape the process at the outset. The adaptive approach established at the beginning was essential to allow for an experimental process that made it possible for those involved to navigate the uncharted research process.

Confronting uncertainty vs. simplification

Both assessments confronted uncertainty as an inherent property of complex systems and of knowledge systems that cannot be tested using traditional scientific techniques. Thus, a significant trade-off was made between, on the one hand, simple data that lent itself to validation and, on the other, information that was more difficult to tease apart but which provided a more realistic reflection of the relationships between drivers of change at broader spatial and temporal scales and realities on the ground.

To deal with the uncertainty this approach generated, the teams sought to validate both scientific and informal knowledge. In the South African assessment, informal knowledge and science were treated as equally powerful sources of knowledge. Informal knowledge was therefore subjected to scientific cross-validation by comparing it to the results of quantitative analyses of, e.g., landscape change and to relevant literature. To deal with uncertainty and fuzzy data in Peru, the concepts of traditional space management were applied to methodologies and tools. Special emphasis was placed on methods and tools that encouraged a diversity of responses, rather than on trying to identify a few methods that would eliminate uncertainty (Martínez-Alier et al. 1998, O'Neill and King 1998). Literature reviews and historical research were integrated with the interpretation of customary practices and norms, and traditional taxonomic systems were complemented with occidental taxonomic systems. Finally, oral informal knowledge was registered through the use of video and then analyzed and validated by the communities concerned. In this way, the uncertainty resulting from a systems approach and democratized expertise was confronted and dealt with.

Although scientific rigor is a significant trade-off in local-level assessments, both studies sought various methods to deal with the uncertainty thus created (Table 2). This process of validation also had the positive effect of encouraging deliberative and reflexive learning as local participants were forced to debate responses and opinions. This does, to some extent, make up for the trade-offs discussed previously.

CONCLUSION

The metaphor of bridging different knowledge systems assumes that there are two known shores: science and informal knowledge. This paper has demonstrated that this is scarcely the case and has hopefully sounded a foghorn or an early warning to assessment teams and researchers alike. Multiple shores exist, both within and between the sciences and informal knowledge. We argue that the metaphor of a boat navigating between unknown shores is a more appropriate metaphor for local-level assessments that adopt a systems approach in dealing with scale, complexity, and epistemology.

As the Peruvian and South African cases have demonstrated, complex systems research allows for different conceptual and practical approaches, and there are various trade-offs involved in the selection of these approaches. By comparing case studies from South Africa and Peru, this paper has explored the different conceptual models that can be used to deal with scale and complexity, the different methods adopted to deal with epistemology, and the different means of dealing with uncertainty. In so doing, the paper has highlighted the conceptual and practical challenges encountered by each assessment, the ways in which each team dealt with these challenges, and the trade-offs involved in those choices.

If local-level studies that embrace a complex systems approach are to add value to analyses taking place at coarser scales, and if these studies are to be meaningfully compared, then researchers who seek to become transdisciplinary must identify the various directions in which their analyses may be pulled. Both case studies discussed in this paper were forced to find practical and conceptual tools that enabled them to meet the needs of their local contexts while at the same time meeting the needs of the broader ecosystem assessment. These tools came from the proverbial toolbox that exists for community-level research. The tools themselves exist because an agreed-upon framework has not yet been developed.

In light of the challenges and trade-offs discussed in this paper, an effective common framework would need to be (1) open enough to be understandable and legitimate to different disciplines and world views; (2) flexible enough to integrate and address different indigenous cosmologies and therefore allow space for knowledge and information from various sources; (3) broad enough to consider multiple spatial and temporal scales while simultaneously acknowledging dynamism, adaptability, nonlinearity, lumpiness, uncertainty, and variability; and (4) capable of dealing with both rigorous and fuzzy data. This is a tall order by anyone's standards, and daunting enough to make most shy away from the complexity involved. Consequently, in the absence even of consensus on whether a single framework adds value or provides yet another means to extend scientific networks, investigators need to continue experimenting and comparing their results. Many more comparative syntheses of divergent case studies and well-planned adaptive experimentation with different approaches are required.

Responses to this article can be read online at:
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