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Moving beyond panaceas: a multi-tiered diagnostic approach for social-ecological analysis

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SUMMARY

Disturbances to key aspects of ecological systems, including biodiversity loss, climate change, pollution and natural resource degradation, have become a major concern to many policy analysts. Instead of learning from the study of biological complexity however, social scientists tend to recommend simple panaceas, particularly government or private ownership, as 'the' way to solve these problems. This paper reviews and assesses potential solutions for such overly simplified institutional prescriptions, referred to here as the 'panacea problem'. In contrast to these simple prescriptions, recent research efforts are now illustrating the diversity of institutions around the world related to environmental conservation. The complexity of working institutions, however, presents a challenge to scholars who equate scientific knowledge with relatively simple models that predict optimal performance if specific institutional arrangements are in place. Dealing with this complexity has led to the development of frameworks as meta-theoretical tools. The institutional analysis and development (IAD) framework has been used over the last three decades as a foundation for a focused analysis of how institutions affect human incentives, actions and outcomes. Building on this foundation, the social-ecological systems (SES) framework has recently enabled researchers to begin the development of a common language that crosses social and ecological disciplines to analyse how interactions among a variety of factors affect outcomes. Such a framework may be able to facilitate a diagnostic approach that will help future analysts overcome the panacea problem. Using a common framework to diagnose the source, and possible amelioration, of poor outcomes for ecological and human systems enables a much finer understanding of these complex systems than has so far been obtained, and provides a basis for comparisons among many systems and ultimately more responsible policy prescriptions.

Keywords: institutions, panaceas, property rights, social-ecological systems, sustainability

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INTRODUCTION

Settings for human–environment interactions are complex. They are composed of diverse ecological systems (including lakes, rivers, fisheries, forests, pastures, the ocean and the atmosphere), as well as human engineered systems (including roads, irrigation systems and communication networks). Finding ways to sustainably govern and manage these systems has become ever more difficult as they have become increasingly interlinked, and as the size of human populations and the level of economic development have both increased. Addressing this complexity must in turn overcome historical academic divisions between ecology, engineering and the social sciences, the tendencies of social scientists to build simplified models of complex systems in order to derive ideal types of governance, and an overreliance on a limited set of research methods to study social and environmental systems. To effectively sustain environmental systems, it is necessary to go beyond frequently-recommended simple panaceas to build general diagnostic frameworks that can be used to conduct rigorous research and achieve better policy analysis. The relevant disciplines need to be built on sounder theory of complex systems, and recognition of the nested levels and near-decomposability in such systems (for example see Brunckhorst 2010).

In this paper, we first provide a brief overview of the current overreliance on panaceas, particularly with respect to the use of idealized property-rights regimes and the need to move beyond simple solutions to difficult and complex problems. Secondly, we review the progress that has been made in recent times in recognizing the need for a diversity of institutional processes that are matched to the scale and characteristics of the particular ecological and cultural systems involved. Specifically, we focus on institutional diversity in forest governance and a research programme concerning co-management of natural resources. Thirdly, we identify property rights within an institutional research programme and explore a relatively recent research programme that focuses on social-ecological systems (SESs). Fourthly, we discuss the relationship between the SES framework and a more diagnostic approach to analysis, as well as the relationship the SES framework has to earlier research on the design principles that appear to underlie sustainable governance systems related to small- and medium-sized common-pool resources. Finally, we discuss some implications these issues have on future research and draw several conclusions.

PANACEAS AND PROPERTY RIGHTS

Modern society faces a diversity of environmental problems, including biodiversity loss, diminishing natural resource stocks and the threat of massive climate change. Humans have developed a range of policy responses in their efforts to cope with environmental problems, with varying degrees of success. Unfortunately, the ability of scientists and analysts to explain and learn from these problems and diverse responses has been limited by a historically simplistic approach to policy analysis. We term this the panacea problem (Brock & Carpenter 2007; Meinzen-Dick 2007; Ostrom *et al.* 2007).

The panacea problem occurs whenever a single presumed solution is applied to a wide range of problems. This problem has two distinct dimensions. The first dimension occurs in situations where a theory is too precise to be flexibly adapted to the range of cases to which it is applied. This dimension has been discussed extensively (Hayek 1945; Scott 1998): a government may fail by homogenizing the diversity of contexts to which it applies its policies and management practices. This first dimension of the panacea problem is sometimes referred to as a blueprint approach to governance, which leads to a lack of fit between programmes and their supposed social-ecological targets (Korten 1980). Numerous examples of this type of policy failure have been documented due to this dimension of the panacea problem. Evans (2004, pp. 30–31) described the problem within international development aid projects: 'Currently, the dominant method of trying to build institutions that will promote development is to impose uniform institutional blueprints on the countries of the global south—a process which I call 'institutional monocropping'. This process has produced profoundly disappointing results.'

Campbell *et al.* (2006) analyzed the failures that have occurred in semi-arid grazing lands owing to the efforts of scholars to discover optimal stocking regimes and the efforts of government agencies to apply them. They suggested 'a lack of connection between the micro-economics literature and natural science and social-anthropological literature' and the need for a recognition 'that policy prescriptions at national or even regional levels are likely to have limited value due to context specificity' (Campbell *et al.* 2006, p. 75). This problem also pervades fisheries policy (St Martin *et al.* 2007). As Degnbol *et al.* (2006, p. 534) discussed: 'Today, disciplinary boundaries narrow the perspective of fisheries management, creating tunnel vision and standardized technical fixes to complex and diverse management problems. . . . We claim that improvements in fisheries management will be realized not through the promotion of technical fixes but instead by embracing and responding to the complexity of the management problem.'

The other dimension of the panacea problem involves theories that are excessively vague instead of excessively precise. This has historically occurred when very general, ideal governance types or property regimes are advocated as being the primary way to manage natural resources successfully. Traditionally, economic and environmental policy analysis and their related fields have been dominated by this approach in the form of the state-market dichotomy (Weimer & Vining 2005).

More recently, some scholars have misunderstood a research programme studying community-based common-pool resource management (NRC [National Research Council] 1986, 2002; Feeny *et al.* 1990; Ostrom 1990) that has illustrated the capacity of the users of a resource to develop and sustain common-property regimes. Based on this misunderstanding, some policy analysts have added a third ideal type to the first two, namely common-property management. Berkes (2007, p. 15189) warned that 'community-based conservation as a blueprint solution threatened to become a panacea itself' (see also Hackel 1999; Barrett *et al.* 2001; Murphree 2002). Unsurprisingly, this has led to a backlash of criticism against community-based natural resource management as a panacea (Shanmugaratnam 1996; Satria *et al.* 2006; but see Dressler *et al.* 2010).

Advocacy for each of these ideal types relies on a widely accepted tenet of environmental management and conservation: that property rights in one form or another over land or some other resource are required in order to provide the right incentives to participants (Hanna & Munasinghe 1995). It is presumed that when someone does not own a resource, they have no long-term interests in sustaining the resource over time and thus cannot be expected to act beneficially towards that resource. Thus, without property rights, open-access conditions prevail, which frequently do lead to environmental destruction (Dasgupta & Heal 1979; Brander & Scott Taylor 1998). The closely related dichotomies of the state versus the market and of private versus public ownership have been fortified in part by falsely presuming that any resource not owned privately or by a government is an open-access resource (Hardin 1968; Alchian & Demsetz 1973). The frequently proposed alternative to open access is one of the two idealized property-rights regimes, namely government or private ownership.

These idealized governance types have been applied to environmental conservation in several ways. One important example has been through the implementation of protected areas and national parks. Private ownership, or a mix of public and private ownership and management, also has a history of promotion and implementation through conservation easements and conservation by farmers and rangers (Western & Wright 1994; Cooper *et al.* 2005; Fairfax *et al.* 2005; Brunson & Huntsinger 2008), and the Convention on Biological Diversity (URL http://www.cbd.int/) stresses the importance of conservation outside of public areas. However, public ownership with stringent formal regulations regarding use patterns is still seen in some circles as the silver bullet to biodiversity conservation (Terborgh 1999; Lovejoy 2006).

As of 2005, approximately 86% of the world's forests were owned by national governments and protected areas had grown to cover *c.* 6.4 million km^2 of forest globally (Agrawal *et al.* 2008). By 2010, the percentage of forest land owned by national governments had decreased to 80% (FAO [Food and Agriculture Organization of the United Nations] 2010), signalling a slight shift away from state-centred and administrated forest governance regimes. Interestingly, Agrawal *et al*. (2008, p. 1462) concluded that 'the effectiveness of forest governance is only partly explained by who owns forests. At the local level, existing research finds only a limited association between whether forests are under private, public, or common ownership and changes in forest cover or sustainability of forest management.'

These results, which are part of a larger research programme we will discuss shortly, illustrate the difficulties that arise from panacea prescriptions. Ideal governance types as panaceas may be so general as to contain little real prescriptive content (Dietz *et al.* 2003). There is, for example, an extremely large number of practical variations of public ownership and governance. This allows for other variables and more specific institutional processes to affect outcomes. In this case the problem is not misplaced precision, but institutional prescriptions that are devoid of meaningful content.

EXAMINING INSTITUTIONAL DIVERSITY

Diversity of forest institutions around the world

Some progress has been made to move forward from the overreliance on panaceas in efforts to improve environmental conservation. An important component of this progress is the extensive empirical research now conducted on the diversity of institutions found around the world that are involved in environmental conservation (Berkes & Turner 2006; Ostrom & Nagendra 2006; Bray 2010). Empirical studies are uncovering a diversity of institutions that achieve sustainable development, as well as those that do not. Several factors beyond the very generalized labels associated with the idealized property-rights regimes discussed above are associated with successes in the field.

Many of these empirical studies have been conducted within the International Forestry Resources and Institutions (IFRI) research programme, active since the early 1990s. At that time, Marilyn Hoskins of the FAO asked Elinor Ostrom whether the Workshop in Political Theory and Policy Analysis would apply their prior theory and methods to forestry resources and begin a long-term collaborative research network of centres located around the world (Gibson *et al.* 2000; Poteete & Ostrom 2004; Wollenberg *et al.* 2007). IFRI programme collaborating centres are now located in Bolivia, Colombia, Guatemala, India, Kenya, Mexico, Nepal, Tanzania, Thailand, Uganda and the USA, with new centres being established in Ethiopia and China. IFRI is the only interdisciplinary long-term monitoring and research programme studying forests owned by governments, private organizations and communities in multiple countries.

Forests are a particularly important form of land cover given their role in climate change related emissions and carbon sequestration (Canadell & Raupach 2008), the biodiversity they contain (Dallmeier & Comiskey 1998), and their contribution to rural livelihoods in developing countries and regions (Shackleton & Shackleton 2004). As mentioned already, government-owned protected areas are frequently recommended as 'the' way of preserving the ecosystem services generated by forests (Terborgh 1999).

In an effort to examine whether government ownership of protected areas is a necessary condition for improving forest density, Hayes (2006) used IFRI data to compare different forest governance types via a rating of forest density (on a five-point scale) assigned to a forest by the forester or ecologist who had supervised the mensuration of trees, shrubs and ground cover in a random sample of forest plots. Of the 163 forests included in the analysis, 76 were government-owned forests legally designated as protected forests, and 87 were public, private or communally owned forested lands used for a wide diversity of purposes. No statistical difference was found between the forest densities in officially designated protected areas and all other forested areas.

Conversely, other IFRI studies have found that lower-level (more specific) variables can be very significant. Gibson *et al.* (2005), for example, examined the monitoring behaviour of 178 forest user groups and, controlling for many other variables, found a strong positive correlation between the level of monitoring and a forester's assessment of forest density. Recent studies by Coleman (2009) and Coleman and Steed (2009) also found that a major variable affecting forest conditions was investment in monitoring by local users. Further, when local users are given harvesting rights, they are more likely to monitor illegal uses themselves. Other studies also stress the relationship between local monitoring and better forest conditions (Banana & Gombya-Ssembajjwe 2000; Ghate & Nagendra 2005; Ostrom & Nagendra 2006; Webb & Shivakoti 2008).

Chhatre and Agrawal (2008) examined the changes in the condition of 152 forests under diverse governance arrangements as affected by the size of the forest, collective action around forests related to improvement activities, size of the user group and the dependence of local users on a forest. They found that 'forests with a higher probability of regeneration are likely to be small to medium in size with low levels of subsistence dependence, low commercial value, high levels of local enforcement, and strong collective action for improving the quality of the forest' (Chhatre & Agrawal 2008, p. 1327).

The legal designation of a forest as a protected area is not by itself related to forest density. Our research shows that forests under different property regimes (government, private or communal) sometimes meet enhanced social goals such as biodiversity protection, carbon storage or improved livelihoods, but sometimes these property regimes fail to provide such goals. Indeed, when governments adopt top-down decentralization policies, leaving local officials and users in the dark, stable forests may become subject to deforestation (Banana *et al.* 2007). Detailed field studies of monitoring and enforcement illustrate the challenge of achieving high levels of forest regrowth without active involvement of local forest users (see Batistella *et al.* 2003; Agrawal 2005; Andersson *et al.* 2006; Tucker 2008). Thus, it is not the general type of forest governance that is crucial in explaining forest conditions; rather, it is how a particular governance arrangement fits the local ecology and social context, how specific rules are developed and adapted over time, and whether users consider the system to be legitimate and equitable (for a more detailed overview of the IFRI research programme, see Poteete *et al.* 2010, chapter 5).

Co-management and polycentricity

Progress has also been made horizontally by considering multiple idealized governance types at once (as opposed to vertically, digging down into the importance of lower-level institutional variables). It has been increasingly recognized that, even within the three ideal governance types, a mix of these idealized property regimes is likely to be more appropriate in many situations than any single one (Lubell 2005; Scholz & Wang 2006). Indeed, many communities associated with common-property arrangements actually employ a mix of common and private property (Ostrom 1990). For example, it is typical in community-based irrigation systems for agricultural parcels of land to be privately owned, while the water and pastures are held as common property (Trawick 2001).

Two or three of the idealized governance types can interact in environmental conservation contexts. For example, recent cap-and-trade programmes effectively combine government management and private ownership of the traded rights (Stavins 2008). One important and now firmly established branch of research explores the outcomes that result from co-management of a natural resource between user groups and governments (Carlsson & Berkes 2005; Borrini-Feyerabend *et al.* 2007; Brunckhorst *et al.* 2008). There is a close relationship between the literature on co-management and the study of institutions as an organizing concept for analysing social systems (Sandström 2009).

Several justifications exist for adopting co-management arrangements to address environmental problems. First, scholars focusing on one level frequently find that processes at another level affect outcomes. Local systems are increasingly affected by external economic events and public policies. This argues for the inclusion of larger governance units when undertaking analysis of small-scale governance arrangements (Agrawal 2003). Meanwhile, others have noted the difficulties that top-down government or international development agency interventions have faced when they do not take local user groups into account (Lam 1998). This finding is also reflected in the IFRI programme. When local users are not involved in any aspect of the planning of a new project, they have no vested interest in the success of the project, and worse, they can directly or indirectly act to undermine it. In contrast, when users are involved, they can potentially use local knowledge to make a governance regime more adaptive, if collaborative arrangements are used to facilitate systematic learning (Armitage *et al.* 2007).

Additionally, particular governance arrangements may have comparative advantages in resolving different types of problems. Local user groups frequently have comparative advantages in gathering and maintaining knowledge of local ecological complexity that would be costly for governments to collect (Moller *et al.* 2004). However, communities may have comparative disadvantages in managing large-scale natural resources and environmental pollution problems (Rose 2002).

Berkes (2002) noted that co-management is not merely a task of assigning components of an environmental problem to various groups of participants and their associated property regimes. Because of cross-scale social and biophysical linkages, the interplay between local and more central governance structures must also be taken into account (Young 2002; Hill *et al.* 2010). Additionally, co-management is not necessarily between a monolithic central government and one coherent community. Rather, it is a more complex arrangement between multiple sources of governance, or what has been referred to as polycentricity (McGinnis 1999; Ostrom 1999*a*, *b*).

A polycentric governance structure may at first seem chaotic. It was a fear of this supposed disorder resulting from the interactions among multiple decision-makers that for decades led many scholars and practitioners to advocate either extreme centralization or extreme decentralization and privatization in order to make decisions the function of one coherent decision-maker (Marshall 2005). However, extensive study of communities of users has established that polycentric arrangements that enable users to develop rules and organizations at multiple levels can work effectively (Ostrom *et al.* 1978; Bromley & Feeny 1992; Ostrom & Parks 1999). Coping with all our present environmental problems will likely require similar polycentric governance arrangements across geographic scales beyond those considered by many community case studies (see Brunckhorst *et al.* 2006).

INSTITUTIONS AND SOCIAL-ECOLOGICAL SYSTEMS

Institutional frameworks

Over the past several decades, there has been a gradual shift in the literature from an exclusive focus on general property-rights regimes to a more inclusive emphasis on the institutions that affect environmental conditions. Institutions are defined as 'potentially linguistic entities . . . that refer to prescriptions commonly known and used by a set of participants to order repetitive, interdependent relationships' where 'prescriptions refer to which actions (or states of the world) are required, prohibited, or permitted' (Ostrom 1986, p. 5). Institutions may be seen as commonly understood codes of behaviour

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that potentially reduce uncertainty, mediate self-interest and facilitate collective action.

Property-rights arrangements or regimes are one important result of institutional processes that affect outcomes. The three broad property-rights regime categories discussed earlier are a function of a myriad of specific rules that govern a particular setting. A functional common-property regime for a grazing pasture, for example, results from many rules, including those that specify rights and conditions for resource access, monitoring and leadership positions, possible sanctions and demands for contributions (Netting 1972). A property right held by an actor results from these rules and enables the actor to take particular actions (Schlager & Ostrom 1992). In this context, the study of property rights becomes part of a more expansive study of the institutions that affect environmental conservation and natural resource management.

Following this transition, the task remains to construct the theories that relate institutional processes, including property rights, to outcomes. We have identified the two extremes in our discussion of the panacea problem: excessively general theories and excessively precise models. Costs are associated with each of these two problems, the first being a lack of meaningful content of overly general theories, and the second being a lack of applicability or accuracy with overly precise models (Cox 2008). Young (2002, p. 175) stated the resulting task for institutional analysts as follows: 'What is necessary, at least at this stage, is an intermediate approach that avoids both pitfalls of excessive generalization and limitations arising from the treatment of each environmental problem as unique.'

Several frameworks have been developed to facilitate the construction of such theories and the institutional analysis of environmental management and conservation. Schlager (2007, p. 294) described the importance of frameworks in scientific progress: 'Frameworks provide theories with the general classes of variables that are necessary to explain phenomena. As theory development proceeds, frameworks may be revised to provide additional content and specificity to general classes of variables.' Thus the relationship between framework and theory development is complementary and reciprocal. One institutional framework with which we are quite familiar is known as the institutional analysis and development (IAD) framework.

The IAD framework is best thought of as a metatheoretical conceptual map that identifies an action situation, patterns of interactions, outcomes and an evaluation of these outcomes (Fig. 1). Efforts to explain collective action in field settings with diverse structures, particularly the complex public economies of USA metropolitan areas and common-property regimes around the world, were the stimuli leading to the development of the IAD framework. The IAD framework is consistent with multiple theories and models, but its closest relationship is to the language of game theory, since the working parts of an action situation and a game are intended to be the same.

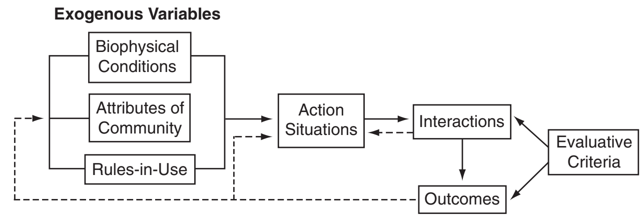

Figure 1 A framework for institutional analysis. Adapted from Ostrom (2005, p. 15).

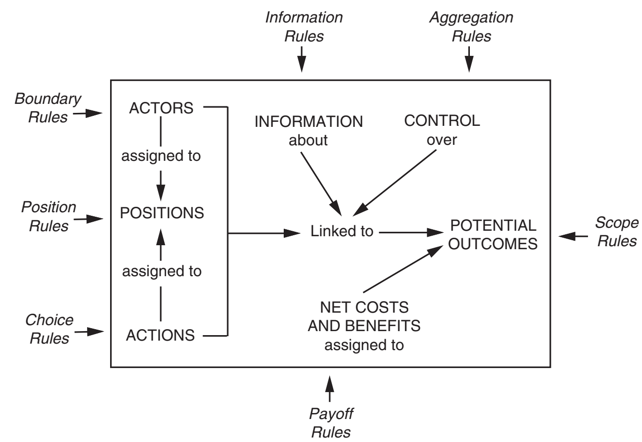

Figure 2 Rules as external variables directly affecting the elements of an action situation. Adapted from Ostrom (2005, p. 189).

An action situation is a central part of the IAD framework, and is internally structured by seven working parts, including (1) the set of actors, (2) the sets of positions actors fill in the context of this situation, (3) the set of allowable actions for actors in each position, (4) the level of control that an individual or group has over an action, (5) the potential outcomes associated with each possible combination of actions, (6) the amount of information available to actors, and (7) the costs and benefits associated with each possible action and outcome. These seven attributes of an action situation can be thought of as core micro variables that affect the preferences, information, strategies and actions of participants. Each attribute can take multiple forms that jointly affect the decisions made by actors. The internal structure of an action situation is itself affected by the relevant biophysical world, the community within which it is located, as well as by the specific rules in use. In light of fieldwork and further analysis, seven types of rules are posited to be most important in affecting outcomes in an action situation, as these are the rules that directly affect each of the internal working parts (Fig. 2).

The IAD framework has been used as the foundation for creating coding forms to be used in an extensive meta analysis of irrigation and fishery cases around the world (see Schlager 1990; Tang 1992), for irrigation systems in Nepal (Shivakoti & Ostrom 2002) and for the extensive studies of forests undertaken by the IFRI network. As such, the framework has proven to be quite useful, and the body of theory produced, particularly in common-pool

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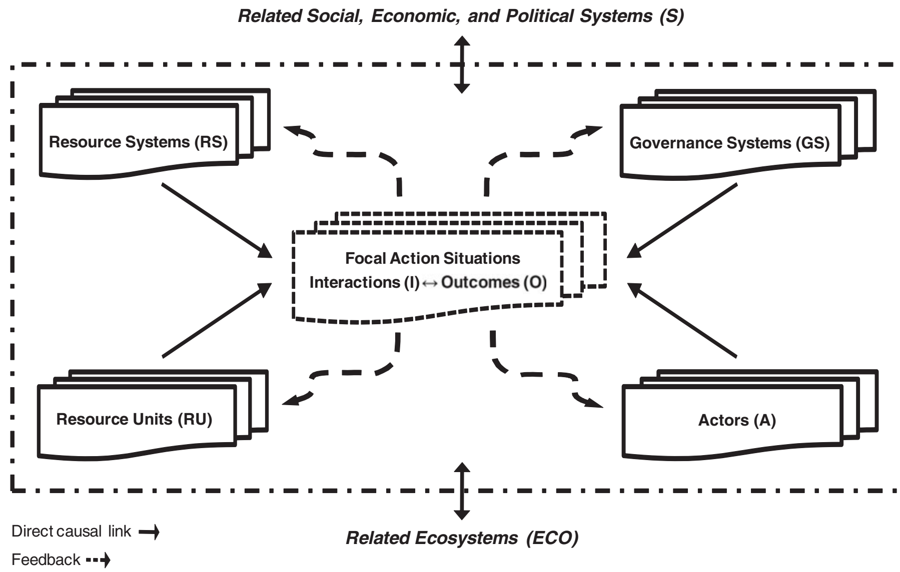

Figure 3 Revised SES framework combining the IAD and SES frameworks (Source: McGinnis 2010).

resource (CPR) settings, is now extensive (Ostrom 2007*a*). However, there have been increasing numbers of calls for a more biophysically sophisticated approach to these settings (Berkes & Folke 1998; Young 2002; Agrawal 2003). It has become increasingly accepted that in order to make progress in environmental conservation theory and practice, an interdisciplinary approach needs to be taken that recognizes the equal importance of social and biophysical variables (Walker & Salt 2006; Brunckhorst 2010). We now turn our discussion to a more recent framework that addresses this issue, among others.

Social-ecological frameworks

Elinor Ostrom (2007*b*, 2009) has introduced a diagnostic framework for the study of complex social-ecological systems (SESs). SESs are defined by Anderies *et al.* (2004) as social systems 'in which some of the interdependent relationships among humans are mediated through interactions with biophysical and non-human biological units.' A primary interest of scholars focusing on SESs has been examining their ability to sustain themselves in the face of disturbances over time, a feature which has been referred to by a wide range of concepts, including adaptive capacity, resilience, robustness, stability and transformability. These terms are used by various communities of scholars for different purposes, leading to some confusion in their meanings. At times they are used interchangeably, and other times different authors use a term in contradictory ways. An important common element, however, is their focus on dynamics of systems over time. This is an important step forward from the traditional 'comparative statics' (see Marshall 2005) approach, and is complementary to the progress in resolving the panacea problem discussed earlier.

McGinnis (2010) presented a revised version of the SES framework, composing a SES of several primary classes of entities, which are in turn embedded in a social, economic and political setting, and in related ecosystems (Fig. 3). Resource systems, resource units, governance systems and social systems composed of actors are the primary components of a SES. A SES can have multiple instances of each of these primary components. For example, within a SES there could be multiple resource systems, such as a forest, a lake and a river system. Each of these entities, in turn, has a set of attributes that can take on various values.

McGinnis (2010) also worked to combine the IAD and the SES frameworks; the primary source of integration is in the component labelled focal action situations (see Fig. 3). McGinnis (2010) conceptualized this as a network of interrelated action situations. To illustrate how this concept can organize the study of a SES, we briefly discuss here the case of the Taos valley *acequias*, a network of community-governed irrigation systems in northern New Mexico (Cox 2010).

Illustrating action situations in a social-ecological system

The approximately 51 acequias in the Taos valley (Fig. 4) have an average of 40 members, and have maintained agricultural productivity over a long period of time in a high-desert environment by maintaining high levels of collective action. This cooperation is required in order to build and sustain the irrigation infrastructure that steers snowmelt-derived surface water from the rivers flowing out of the eastward mountains out onto their irrigation fields. Each acequia is organized by a common-property arrangement to distribute its water and maintain its infrastructure, and is governed by an executive *mayordomo* and a set of three administrative commissioners who carry out these arrangements.

The Taos valley acequias use two primary levels of governance: one within each acequia and another between groups of acequias. We can conceive of these as being two different classes of action situations. The primary function of having these two classes is to create a two-tiered governance structure that minimizes the number of actors involved in any

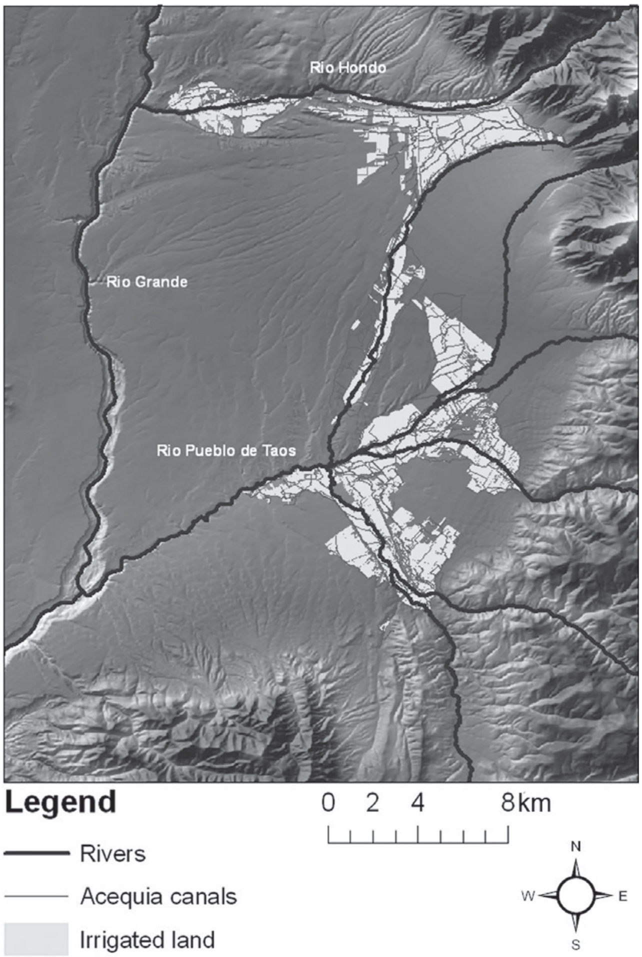

Figure 4 Map of the Taos valley and acequia irrigated land.

one action situation. With fewer actors, transaction costs are lowered and trust and reciprocity are more easily maintained. This is done in two steps. First, the larger SES that the Taos valley acequias constitute is broken up into the 51 acequias, each of which has its own independent decision-making arrangements developed to resolve internal collective-action problems. This creates a set of action situations within each acequia with regard to the important collective tasks that must be accomplished, such as infrastructure provision as a public good and the distribution of water.

These action situations do not, however, resolve collective-action problems among acequias, as many of them are along the same rivers and have the same upstream-downstream relationship as do their individual members with each other. What is needed is a second set of action situations that take place among sets of acequias. The actors that participate in these settings are a subset of the acequia membership, namely the acequia mayordomos and commissioners. Because it is primarily the acequia officers who participate in these water-sharing agreements (*repartimientos*), the number of actors, and thereby the magnitude of the transaction costs, is also kept low at this second level of governance. Through these repartimientos, the acequias are able to maintain at least some level of cooperation in the distribution of water along the entire reach of a river.

These two types of action situations do not exhaust the arenas of decision-making that are relevant for the acequias. Local courts, for example, have frequently been an important source of conflict resolution for the acequias. This system has sustained the acequias for several hundred years. However, dramatic changes during the past several decades have altered the traditional incentives and disrupted the functioning of these irrigation systems. These changes include emigration of younger members, the introduction of a tourist economy and wealthy landowners, and an accompanying low-wage labour-market into the area.

A DIAGNOSTIC APPROACH

Continuing to unpack the SES framework

We now discuss the concept of diagnosis and how it may be facilitated by the SES framework. Diagnosis traditionally means ascertaining the nature or cause of something, usually of an unwanted condition. Tied to a diagnosis is the idea that different types of causes have implications for the efficacy of different types of treatments. The possible amelioration of a condition by successfully applying a particular treatment is the motivation for the process. Our interest in the process of diagnosis here is to explore the possibility of its use in overcoming the panacea problem discussed earlier.

The concept of diagnosis is not novel to its application to environmental conservation and natural resource management. The field of medicine has faced a long struggle in its efforts to overcome the recommendation of panaceas, such as various purges and use of aspirin, to solve an immense variety of physical ailments. Over time, biology has developed a rigorous nested approach to the study of the human body and medicine has adopted a diagnostic approach to understanding the problems related to individual health. Instead of offering one or a few general remedies for most problems (as was common in the nineteenth century), a doctor now asks several initial questions about the potential sources of a health problem and then probes deeper using X-rays and other diagnostic tools after assessing information about higher-level indicators (such as temperature, blood pressure, weight change and reported pain levels). Scholars and practitioners concerned with preserving the environment and maintaining its vital functions still need to develop a rigorous nested approach to analysis.

In the previous section we briefly explored some features of the SES framework. One feature we have not yet discussed is its multi-tiered quality. The primary entities (Fig. 3) are the first level of the framework. These are each associated with a set of attributes, which can, in turn, be decomposed into a set of subattributes to form the second level (or third level) of the framework (Fig. 5). These attributes can work to form particular types of entities that possess them, and it would be possible to arrange these types into hierarchical taxonomies.

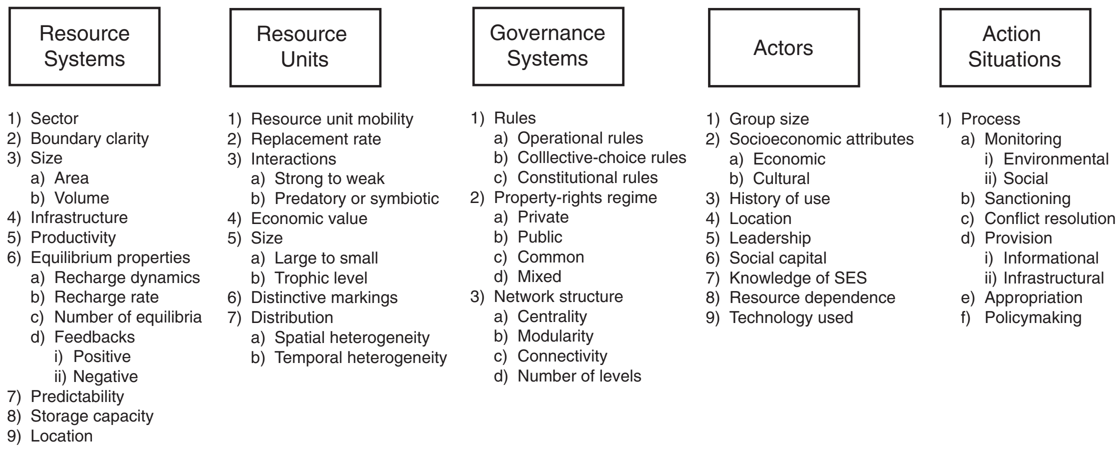

Figure 5 Unpacking the SES framework into multiple levels.

Depending upon an array of attributes, there may be different types of resource systems, for example, or different types of governance systems. There may also be different types of processes occurring within action situations. For example, social and environmental monitoring are two subtypes of the broader process of monitoring.

This typological decomposition, which we leave for future work, is important for the diagnostic approach, because it enables analysis of different types of environmental problems and systems in order to determine what have been the most effective types of social-institutional responses to various types of natural systems and problems. This point was reinforced by Young (2002, p. 176), when he discussed the importance of a diagnostic approach in addressing environmental problems: 'the diagnostic approach seeks to disaggregate environmental issues, identifying elements of individual problems that are significant from a problem-solving perspective and reaching conclusions about design features necessary to address each element.'

Diagnosis and design principles

The SES framework discussed so far is exploratory and tentative. Nevertheless, it can help scholars move beyond the panacea problem by providing multiple levels of analysis. Across levels of the framework, an analyst can determine what is critically important in determining outcomes for one case, or for a whole set of cases. The larger the number of cases under examination, the more general the approach required, using the first or second levels of analysis, in order to produce accurate theories. This observation follows from the principle that at higher levels of aggregation, patterns can be more predictably found across a set of observations (Levin 1992, 1999). Thus, for a large number of cases, highly specific rules that produce particular outcomes across every case are unlikely to be found. What is more likely is that, when generalizing to a large number of cases, broad social and biophysical attributes associated with general categories of outcomes may be identified.

An example of this process and this principle is the development of a set of institutional design principles (Ostrom 1990), which characterize long-lasting community-based natural resource management systems. Ostrom (1990) had searched for specific rules that might persist across many of these systems, but could not find a specific pattern; however, in agreement with Levin's principle, Ostrom (1990) found coarser patterns which were embodied in the design principles. Cox *et al.* (2010) have analysed 91 studies produced since Ostrom's (1990) original work that evaluate the principles, and found them to be moderately well-supported. We summarize their central findings here:

(1) Support for the principles was consistent across the primary sectors examined (forests, fisheries, pasture and irrigation).
(2) Support did not differ significantly between empirical studies that explicitly examined the principles and those that examined them implicitly.
(3) Conditions stipulated by each individual principle were significantly more likely to be found in successful cases of community-based natural resource management than in unsuccessful cases, and these conditions were significantly more likely to be absent in unsuccessful cases than in successful cases.
(4) Much of the criticism and lack of support for the principles came from abstract studies. Empirical studies (case studies, syntheses and large-*n* statistical analyses), which presented evidence for or against one or more particular principles, were moderately supportive of the principles.

In their review, Cox *et al.* (2010) also discussed several prominent critiques of Ostrom's principles that have arisen since their introduction. As implied by the list above, these criticisms were primarily abstract or theoretical. The main empirical criticism was that the principles did not exhaustively list all the relevant factors associated with sustainability, and this is certainly the case. The primary theoretical criticism found in the literature was that the design principles represent just the panacea problem discussed above. The principles are seen by some scholars as an example of the first type of panacea problem: overspecificity. They are seen as representing an overgeneralization to a broad range of cases, abstracting excessively from local context and history of particular cases (Cleaver 1999, 2000; Steins & Edwards 1999; Young 2002; Blaikie 2006).

We can use the SES framework and the discussion thus far to better understand this issue. In constructing the principles, Ostrom initially was looking for specific rules that typified successful long-lasting systems. In the absence of such specific patterns, Ostrom resorted to more aggregated conditions that she labelled design principles. In doing so, she traded off specificity for more general applicability.

Several of the principles mentioned by Ostrom are processes that occur within action situations, such as graduated sanctioning and monitoring by accountable monitors. Processes in action arenas result, or emerge, from a configuration of social and biophysical factors, not just one particular rule (Figs. 1–2). This is why it was difficult for Ostrom (1990) to find patterns at the more specific level of individual rules; because they are merely one component of a complex configuration producing emergent processes and outcomes (see also fig. 1 in Brunckhorst 2010). When other elements of a configuration change, the effects of a particular rule are likely to change as well. However, the more general conditions stipulated by the principles can be satisfied by a variety of these configurations. The condition of monitoring, for example, encompasses a diversity of configurations of social and biophysical factors that may produce such a condition, and thus can avoid excessive specificity.

Other design principles correspond to important level 2 variables. Along with the other general high-level attributes of the main components of a SES, the design principles can serve as a starting point for a diagnostic approach to the study of complex SESs. These highly aggregated attributes include the idealized property-rights regimes discussed earlier. To conclude, the design principles lack an important degree of specificity. This is a limitation, because they are less precise than a more specific theory could be. It is also a potential strength, in that they may avoid the panacea problem of overspecificity, and serve as part of a basis for a diagnostic approach to analysis.

FUTURE WORK

We have reviewed the panacea problem, which needs to be confronted in order to advance the science and the practice of environmental conservation. We have also presented some potential advances in accomplishing this task, and discussed the multi-tiered interdisciplinary framework that, once fully developed, can capture social-ecological properties and dynamics to promote understanding of complex SESs. However, much work remains to firmly establish a research programme using a diagnostic approach that facilitates the accumulation of empirical data on both social and biophysical variables at multiple levels of aggregation. Several promising areas in which such work could be done can be identified.

To begin, our discussion has focused primarily on the structural properties of social-ecological situations, without much discussion of the dynamics or processes that occur within them. Ecosystem ecology, which, in addition to focusing on ecosystem structure, emphasizes the study of flows of material and energy through ecosystems, may provide a lesson in understanding dynamics (Chapin *et al.* 2002). A similar approach could be taken to the study of SESs. One way may be to introduce a typology of disturbances that may affect SESs over time (Schoon & Cox 2010), thus moving beyond a historically static (or comparative static) approach to the study of social systems and SESs. This method may thus incorporate more ecological components and dynamics into frameworks and studies, which are currently underemphasized in this work.

In addition to this consideration, the approach here has several methodological implications. The SES framework, and the diagnostic perspective more generally, requires that case studies be conducted, where an analyst examines one case at various levels of specificity or generality, as needed. These case studies can be useful in stimulating new theoretical developments: 'close examination of individual cases offers opportunities to develop concepts and theory, identify the limits of general relationships and disprove deterministic hypotheses, control for confounding effects through within-case comparisons, and disentangle causal processes' (Poteete *et al.* 2010, p. 33).

Following the completion of a number of case studies, the research programme can move to a different well-established methodology, namely meta-analyses (Ostrom 1990; Pagdee *et al.* 2006; Rudel 2008; Cox *et al.* 2010). Meta-analysis here would initially involve coding a set of cases consistently through the SES framework. A challenge that previous efforts have faced is the lack of consistency in what variables are discussed in individual cases. Previous meta-analyses have had to review a large number of cases to identify a small set that contained information about the same set of variables (Ostrom *et al.* 1994; Pagdee *et al.* 2006). This problem can begin to be addressed by conducting case studies with the SES framework in mind at the outset. This, in turn, will help those case studies by guiding the analyst towards the possible variables for consideration.

Following data coding, the next step is to look for patterns across cases. According to Levin's (1992, 1999) principle, there are more likely to be consistent patterns across many cases at higher levels of aggregation in the framework. For example, it is likely that across the majority of cases, some form of environmental monitoring of the condition of an appropriated resource will be advantageous. This is a general enough condition that it may not depend on the presence or value of more specific variables. The methods most likely to be useful in finding these patterns are descriptive and inferential statistics.

At lower levels of aggregation, cases will be more distinct, and traditional statistical techniques will be less successful at identifying generalities. For example, each SES that employs some form of environmental monitoring will probably conduct it with a unique set of specific rules that it does not share with other SESs. To examine these lower levels, small and medium sample-size methodologies, such as within-case process tracing (George & Bennett 2005), cross-case comparisons and qualitative-comparative analysis (Ragin 1987, 2008) may be used.

At these higher levels of specificity, the kinds of theories sought are what George and Bennett (2005) referred to as typological theories. A typological theory is 'a theory that specifies independent variables, delineates them into the categories for which the researcher will measure the cases and their outcomes, and provides not only hypotheses on how these variables operate individually, but also contingent generalizations on how and under what conditions they behave in specified conjunctions or configurations to produce effects on specified dependent variables' (George & Bennett 2005, p. 235).

Typological theorizing, and the broader approach advocated here, is consonant with the paradigm of adaptive natural resource management, which emphasizes complex interactions revealed in part through case-based work, and a movement away from 'command-and-control' approaches that focus exclusively on one or a few target variables (Johnson *et al.* 1999). This command-and-control approach, which produces management prescriptions using highly simplified models, is very similar to the panacea problem as we have described it.

In this typological context, independent variables become more like causal conditions, and these conditions form a configuration of values that constitutes a specific case (Ragin 2000). One way of viewing the SES framework is as a means for typologically decomposing resource systems and units, governance systems and actors, based on their properties and the properties of their subcomponents. A typological theory can then be thought of as relating these subtypes in various arrangements to outcomes.

To conclude, new knowledge created through this process can be brought to bear on existing social-ecological problems, of which there are many. This application process faces its own challenges. While there is no panacea for linking knowledge to action, Cash *et al.* (2003, p. 8089) presented some preliminary findings on how this may be accomplished for the novel field of sustainability science, of which we conceive this work to be a part, most importantly, 'all else being equal, those systems that made a serious commitment to managing boundaries between expertise and decision making more effectively linked knowledge to action than those that did not.' In order to overcome the panacea problem, an important amount of work and innovation must occur conceptually, methodologically and practically in order to build a new research programme on the sustainability of complex SESs.

CONCLUSIONS

It will be a challenge to move beyond overly simplistic models of environmental and social processes and the accompanying recommendations for relatively simple blueprint property-rights systems as 'the' way to solve environmental problems. To do the social-ecological work that is needed will require knowledge and perspectives from scientific disciplines that are frequently isolated from one another. It will also require a novel integration of methodologies to study social and environmental processes. Enabling scholars from multiple disciplines to share a common framework for diagnosing the sources of diverse environmental problems will take time and effort within a dedicated research programme.

The empirical analyses and frameworks we presented above are good foundation for this work. Considerable further analysis, modification and reformulation are needed, however, before the goal of strong interdisciplinary knowledge of complex SESs is achieved. Understanding the dynamics of differently structured SESs and how diverse interventions may increase or decrease sustainability of these systems over time is a major undertaking. While this will be difficult, we hope that our discussion of the panacea problem has illustrated the importance of doing the hard work to overcome overly simplified responses to serious environmental problems that have unfortunately typified previous work. Hopefully, future work can address these problems, creating and profiting from a dialogue between scientists of different disciplines, as well as between scientists and practitioners, under the auspices of an applied science of sustainability.

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References

Agrawal, A. (2003) Sustainable governance of common-pool resources: context, methods, and politics. *Annual Review of Anthropology* **32**: 234–262.

Agrawal, A. (2005) *Environmentality: Technologies of Government and the Making of Subjects*. Durham, NC, USA: Duke University Press.

Agrawal, A., Chhatre, A. & Hardin, R. (2008) Changing governance of the world's forests. *Science* **320**: 1460–1462.

Alchian, A. & Demsetz, H. (1973) The property right paradigm. *Journal of Economic History* **33**(1): 16–27.

Anderies, J.M., Janssen, M. & Ostrom, E. (2004) A framework to analyze the robustness of social-ecological systems from an institutional perspective. *Ecology and Society* **9**(1): 18.

Andersson, K., Gibson, C. & Lehoucq, F. (2006) Municipal politics and forest governance: comparative analysis of decentralization in Bolivia and Guatemala. *World Development* **34**(3): 576–595.

Armitage, D., Berkes, F. & Doubleday, N., eds (2007) *Adaptive Co-Management: Collaboration, Learning and Multi-Level Governance*. Vancouver, Canada: University of British Columbia Press.

Banana, A.Y. & Gombya-Ssembajjwe, W. (2000) Successful forest management: the importance of security of tenure and rule enforcement in Ugandan forests. In: *People and Forests: Communities, Institutions, and Governance*, ed. C.C. Gibson, M.A. McKean & E. Ostrom, pp. 87–98. Cambridge, MA, USA: MIT Press.

Banana, A.Y., Vogt, N., Bahati, J. & Gombya-Ssembajjwe, W. (2007) Decentralized governance and ecological health: why local institutions fail to moderate deforestation in Mpigi District of Uganda. *Scientific Research and Essays* **2**(10): 434–445.

Barrett, C.B., Brandon, K., Gibson, C. & Gjertsen, H. (2001) Conserving tropical biodiversity amid weak institutions. *Bioscience* **51**: 497–502.

Batistella, M., Robeson, S. & Moran, E.F. (2003) Settlement design, forest fragmentation, and landscape change in Rondônia, Amazônia. *Photogrammetric Engineering and Remote Sensing* **69**(7): 805–812.

Berkes, F. (2002) Cross-scale institutional linkages: perspectives from the bottom up. In: *The Drama of the Commons*, ed. E. Ostrom, T. Dietz, N. Dolšak, P.C. Stern, S. Stonich & E.U. Weber, pp. 293–322. Washington, DC, USA: National Academies Press.

Berkes, F. (2007) Community-based conservation in a globalized world. *Proceedings of the National Academy of Sciences* **104**(39): 15188–15193.

Berkes, F. & Folke, C. (1998) *Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience*. Cambridge, MA, USA: Cambridge University Press.

Berkes, F. & Turner, N.J. (2006) Knowledge, learning and the evolution of conservation practice for social-ecological system resilience. *Human Ecology* **34**(4): 479–494.

Blaikie, P. (2006) Is small really beautiful? Community-based natural resource management in Malawi and Botswana. *World Development* **34**(11): 1942–1957.

Borrini-Feyerabend, G., Pimbert, M., Farvar, M.T., Kothari, A. & Renard, Y. (2007) *Sharing Power: Learning-By-Doing in Co-Management of Natural Resources*. London, UK: Earthscan.

Brander, J.A. & Scott Taylor, M. (1998) Open access renewable resources: trade and trade policy in a two-country model. *Journal of International Economics* **44**: 181–209.

Bray, D.B. (2010) Capitalism meets common-property. *Americas Quarterly* **Winter**: 30–35.

Brock, W.A. & Carpenter, S.R. (2007) Panaceas and diversification of environmental policy. *Proceedings of the National Academy of Sciences* **104**(39): 15206–15211.

Bromley, D., Feeny, D., McKean, M., Peters, P., Gilles, J., Oakerson, R., Runge, C.F. & Thomson, J., eds. (1992) *Making the Commons Work: Theory, Practice, and Policy*. San Francisco, CA, USA: ICS Press.

Brunckhorst, D.J. (2010) Using context in novel community-based natural resource management: landscapes of property, policy and place. *Environmental Conservation* **37**(1): 16–22.

Brunckhorst, D., Coop, P. & Reeve, I. (2006) 'Eco-civic' optimisation: a nested framework for planning and managing landscapes. *Landscape and Urban Planning* **72**(5): 117–134.

Brunckhorst, D., Reeve, I., Morley, P. & Bock, K. (2008) Strategic spatial governance: deriving social–ecological frameworks for managing landscapes and regions. In: *Landscape Analysis and Visualisation: Spatial Models for Natural Resource Management and Planning*, ed. C. Pettit, W. Cartwright, I. Bishop, K. Lowell, D. Pullar & D. Duncan, pp. 253–276. Berlin, Germany: Springer.

Brunson, M.W. & Huntsinger, L. (2008) Ranching as a conservation strategy: can old ranchers save the new west? *Rangeland Ecology and Management* **61**(2): 137–147.

Campbell, B.M., Gordon, I.J., Luckert, M.K., Petheram, L. & Vetter, S. (2006) In search of optimal stocking regimes in semi-arid grazing lands: one size does not fit all. *Ecological Economics* **60**(1): 75–85.

Canadell, J.G. & Raupach, M.R. (2008) Managing forests for climate change mitigation. *Science* **320**: 1456–1457.

Carlsson, L. & Berkes, F. (2005) Co-management: concepts and methodological implications. *Journal of Environmental Management* **75**: 65–76.

Cash, D.W, Clark, W.C., Alcock, F., Dickson, N.M., Eckley, N., Guston, D.H., Jager, J. & Mitchell, R.B. (2003) Knowledge systems for sustainable development. *Proceedings of the National Academy of Sciences* **100**(14): 8086–8091.

Chapin, F.S., Matson, P.A. & Mooney, H.A. (2002) *Principles of Terrestrial Ecosystem Ecology*. New York, NY, USA: Springer.

Chhatre, A. & Agrawal, A. (2008) Forest commons and local enforcement. *Proceedings of the National Academy of Sciences* **105**(36): 13286–13291.

Cleaver, F. (1999) Paradoxes of participation: questioning participatory approaches to development. *Journal of International Development* **11**: 597–612.

Cleaver, F. (2000) Moral ecological rationality, institutions and the management of common property resources. *Development and Change* **31**(2): 361–383.

Coleman, E. (2009) Institutional factors affecting ecological outcomes in forest management. *Journal of Policy Analysis and Management* **28**(1): 122–146.

Coleman, E. & Steed, B. (2009) Monitoring and sanctioning in the commons: an application to forestry. *Ecological Economics* **68**(7): 2106–2113.

Cooper, J., Bernstein, J. & Claasen, R. (2005) Overview of agri-environmental programmes in the European Union and the United States. *Farm Policy Journal* **2**:31–41.

Cox, M. (2008) Balancing accuracy and meaning in common-pool resource theory. *Ecology and Society* **13**(2): 44.

Cox, M. (2010) Exploring the dynamics of social-ecological systems: the case of the Taos valley acequias. Ph.D. dissertation, Indiana University, Indiana, USA.

Cox, M., Arnold, B. & Villamayor-Tomas, S. (2010) A review of design principles for community-based natural resource management. *Ecology and Society* (in press).

Dallmeier, F. & Comiskey, J.A. (1998) *Forest Biodiversity in North, Central and South America, and the Caribbean: Research and Monitoring*. Paris, France: UNESCO.

Dasgupta, P. & Heal, G.M. (1979) *Economic Theory and Exhaustible Resources*. Cambridge, MA, USA: Cambridge University Press.

Degnbol, P., Gislason, H., Hanna, S., Jentoft, S., Raakjær, J., Nielsen, Sverdrup-Jensen, S. & Clyde Wilson, D. (2006) Painting the floor with a hammer: technical fixes in fisheries management. *Marine Policy* **30**: 534–543.

Dietz, T., Ostrom, E. & Stern, P.C. (2003) The struggle to govern the commons. *Science* **302**(5652): 1907–1912.

Dressler, W., Büscher, B., Schoon, M., Brockington, D., Hayes, T., Kull, C.A., McCarthy, J. & Shrestha, K. (2010) From hope to crisis and back again? A critical history of the global CBNRM narrative. *Environmental Conservation* **37**(1): 5–15.

Evans, P. (2004) Development as institutional change: the pitfalls of monocropping and the potentials of deliberation. *Studies in Comparative International Development* **38**(4): 30–52.

Fairfax, S.K., Gwin, L., King, M.A., Raymond, L. & Watt, L.A. (2005) *The Limits of Land Acquisition as a Conservation Strategy, 1780–2004*. Cambridge, MA, USA: MIT Press.

FAO (2010) *Global Forest Resources Assessment 2010*. Rome, Italy: FAO.

Feeny, D., Berkes, F., McCay, B.J. & Acheson, J.M. (1990) The tragedy of the commons: twenty-two years later. *Human Ecology* **18**(1): 1–19.

George, A.L. & Bennett, A. (2005) *Case Studies and Theory Development in the Social Sciences*. Cambridge, MA, USA: MIT Press.

Ghate, R. & Nagendra, H. (2005) Role of monitoring in institutional performance: forest management in Maharashtra, India. *Conservation and Society* **3**(2): 509–532.

Gibson, C.C., McKean, M.A. & Ostrom, E., eds. (2000) *People and Forests: Communities, Institutions, and Governance*. Cambridge, MA, USA: MIT Press.

Gibson, C.C., Williams, J.T. & Ostrom, E. (2005) Local enforcement and better forests. *World Development* **33**(2): 273–284.

Hackel, J.D. (1999) Community conservation and the future of Africa's wildlife. *Conservation Biology* **13**(4): 726–734.

Hanna, S. & Munasinghe, M. (1995) *Property Rights in a Social and Ecological Context; Case Studies and Design Principles*. Washington, DC, USA: The Beijer International Institute of Ecological Economics and The World Bank.

Hardin, G. (1968) The tragedy of the commons. *Science* **162**(3859): 1243–1248.

Hayek, F. (1945) The use of knowledge in society. *American Economic Review* **35**(4): 519–530.

Hayes, T. (2006) Parks, people, and forest protection: an institutional assessment of the effectiveness of protected areas. *World Development* **34**(12): 2064–2075.

Hill, R., Williams, K J., Pert, P.L., Robinson, C.J., Dale, A.P., Westcott, D.A., Grace, R.A. & O'Malley, T. (2010) Adaptive community-based biodiversity conservation in Australia's tropical rainforests. *Environmental Conservation* **37**(1): 73–82.

Johnson, K., Swanson, F., Herring, M. & Greene, S. (1999) *Bioregional Assessments: Science at the Crossroads of Management and Policy*. Washington, DC, USA: Island Press.

Korten, D.C. (1980) Community organization and rural development: a learning process approach. *Public Administration Review* **40**(5): 480–511.

Lam, W.-F. (1998) *Governing Irrigation Systems in Nepal: Institutions, Infrastructure, and Collective Action*. San Francisco, CA, USA: ICS Press.

Levin, S.A. (1992) The problem of pattern and scale in ecology. *Ecology* **73**: 1943–1967.

Levin, S.A. (1999) *Fragile Dominion: Complexity and the Commons*. Cambridge, MA, USA: Perseus Books.

Lovejoy, T.E. (2006) Protected areas: a prism for a changing world. *Trends in Ecology and Evolution* **21**: 329–333.

Lubell, M. (2005) Public learning and grassroots cooperation. In: *Adaptive Governance and Water Conflict: New Institutions for Collaborative Planning*, ed. J.T. Scholz & B. Stiftel, pp. 174–184. Washington, DC, USA: Resources for the Future Press.

Marshall, G. (2005) *Economics for Collaborative Environmental Management: Renegotiating the Commons*. London, UK: Earthscan.

McGinnis, M. (1999) *Polycentricity and Local Public Economies: Readings from the Workshop in Political Theory and Policy Analysis*. Ann Arbor, MI, USA: University of Michigan Press.

McGinnis, M. (2010) Building a programme for institutional analysis of social-ecological systems: a review of revisions to the SES framework. Working Paper. Workshop in Political Theory and Policy Analysis, Indiana University, Bloomington, IN, USA.

Meinzen-Dick, R. (2007) Beyond panaceas in water institutions. *Proceedings of the National Academy of Sciences* **104**(39): 15200–15206.

Moller, H., Berkes, F., Lyver, P.O. & Kislalioglu, M. (2004) Combining science and traditional ecological knowledge: monitoring populations for co-management. *Ecology and Society* **9**(3): 2.

Murphree, M.W. (2002) Protected areas and the commons. *Common Property Resource Digest* **60**: 1–3.

Netting, R.M. (1972) Of men and meadows: strategies of alpine land use. *Anthropological Quarterly* **45**: 132–144.

NRC (1986) *Proceedings of the Conference on Common Property Resource Management*. Washington, DC, USA: National Academies Press.

NRC (2002) *The Drama of the Commons*. Washington, DC, USA: National Academies Press.

Ostrom, E. (1986) An agenda for the study of institutions. *Public Choice* **48**(1): 3–25.

Ostrom, E. (1990) *Governing the Commons: The Evolution of Institutions for Collective Action*. New York, NY, USA: Cambridge University Press.

Ostrom, E. (2005) *Understanding Institutional Diversity*. Princeton, NJ, USA: Princeton University Press.

Ostrom, E. (2007*a*). Institutional rational choice: an assessment of the institutional analysis and development framework. In: *Theories of the Policy Process*, 2nd edition, ed. P.A. Sabatier, pp. 21–64. Boulder, CO, USA: Westview Press.

Ostrom, E. (2007*b*) A diagnostic approach for going beyond panaceas. *Proceedings of the National Academy of Sciences* **104**(39): 15181–15187.

Ostrom, E. (2009) A general framework for analyzing sustainability of social-ecological systems. *Science* **325**: 419–422.

Ostrom, E. & Nagendra, H. (2006) Insights on linking forests, trees, and people from the air, on the ground, and in the laboratory. *Proceedings of the National Academy of Sciences* **103**(51): 19224–19231.

Ostrom, E. & Parks, R.B. (1999) Neither gargantua nor the land of lilliputs: conjectures on mixed systems of metropolitan organization. In: *Polycentricity and Local Public Economies: Readings from the Workshop in Political Theory and Policy Analysis*, ed. M. McGinnis, pp. 284–305. Ann Arbor, MI, USA: University of Michigan Press.

Ostrom, E., Gardner, R. & Walker, J. (1994) *Rules, Games, and Common-Pool Resources*. Ann Arbor, MI, USA: University of Michigan Press.

Ostrom, E., Janssen, M. & Anderies, M.A. (2007) Going beyond panaceas. *Proceedings of the National Academy of Sciences* **104**(39): 15176–15178.

Ostrom, E., Parks, R.B. & Whitaker, G.P. (1978) *Patterns of Metropolitan Policing*. Cambridge, MA, USA: Ballinger.

Ostrom, V. (1999*a*) Polycentricity (Part 1). In: *Polycentricity and Local Public Economies: Readings from the Workshop in Political Theory and Policy Analysis*, ed. M. McGinnis, pp. 52–74. Ann Arbor, MI, USA: University of Michigan Press.

Ostrom, V. (1999*b*) Polycentricity (Part 2). In: *Polycentricity and Local Public Economies: Readings from the Workshop in Political Theory and Policy Analysis*, ed. M. McGinnis, pp. 119–138. Ann Arbor, MI, USA: University of Michigan Press.

Pagdee, A., Kim, Y. & Daugherty, P.J. (2006) What makes community forest management successful: a meta-study from community forests throughout the world. *Society and Natural Resources* **19**(1): 33–52.

Poteete, A.R. & Ostrom, E. (2004) Heterogeneity, group size and collective action: the role of institutions in forest management. *Development and Change* **35**(3): 437–461.

Poteete, A.R., Janssen, M. & Ostrom, E. (2010) *Working Together: Collective Action, the Commons, and Multiple Methods in Practice*. Princeton, NJ, USA: Princeton University Press.

Ragin, C.C. (1987) *The Comparative Method: Moving Beyond Qualitative and Quantitative Strategies*. Berkeley and Los Angeles, CA, USA: University of California Press.

Ragin, C.C. (2000) *Fuzzy Set Social Science*. Chicago, IL, USA: University of Chicago Press.

Ragin, C.C. (2008) *Redesigning Social Inquiry: Fuzzy Sets and Beyond*. Chicago, IL, USA: University of Chicago Press.

Rose, C. (2002) Common property, regulatory property, and environmental protection: comparing community-based management to tradable environmental allowances. In: *The Drama of the Commons*, ed. E. Ostrom, T. Dietz, N. Dolšak, P.C. Stern, S. Stonich & E. Weber, pp. 233–258. Washington, DC, USA: National Academies Press.

Rudel, T.K. (2008) Meta-analysis of case studies: a method for studying regional and global climate change. *Global Environmental Change* **18**(1): 18–25.

Sandström, C. (2009) Institutional dimensions of comanagement: Participation, power and process. *Society and Natural Resources* **22**: 230–244

Satria, A., Matsuda, Y. & Sano, M. (2006) Questioning community based coral reef management systems: case study of Awig-Awig in Gili Indah, Indonesia. *Environment, Development and Sustainability* **8**: 99–118.

Schlager, E. (1990) Model specification and policy analysis: the governance of coastal fisheries. PhD dissertation, Indiana University, USA.

Schlager, E. (2007) A comparison of frameworks, theories, and models of policy processes. In: *Theories of the Policy Process*, 2nd edition, ed. P.A. Sabatier, pp. 293–320. Boulder, CO, USA: Westview Press.

Schlager, E. & Ostrom, E. (1992) Property-regimes and natural resources: a conceptual analysis. *Land Economics* **68**(3): 249–262.

Scholz, J.T. & Wang, C-L. (2006) Cooptation or transformation? Local policy networks and federal regulatory enforcement. *American Journal of Political Science* **50**(1): 81–97.

Schoon, M. & Cox, M. (2010) Understanding disturbances and responses in social-ecological systems. *Society and Natural Resources.* In press.

Scott, J. (1998) *Seeing Like a State: How Certain Schemes to Improve the Human Condition have Failed*. New Haven, CT, USA: Yale University Press.

Shackleton, C. & Shackleton, S. (2004) The importance of non-timber forest products in rural livelihood security and as safety nets: a review of evidence from South Africa. *South African Journal of Science* **100**: 658–664.

Shanmugaratnam, N. (1996) Nationalisation, privatisation, and the dilemmas of common property management in western Rajasthan. *Journal of Development Studies* **33**: 163–187.

Shivakoti, G.P. & Ostrom, E., eds. (2002) *Improving Irrigation Governance and Management in Nepal*. San Francisco, CA, USA: ICS Press.

St Martin, K., McCay, B.J., Murray, G., Johnson, T. & Oles, B. (2007) Communities, knowledge and fisheries of the future. *International Journal of Global Environmental Issues* **7**(2/3): 221–239.

Stavins, R.N. (2008) Addressing climate change with a comprehensive U.S. cap-and-trade system. *Oxford Review of Economic Policy* **24**(2): 298–321.

Steins, N.A. & Edwards, V.M. (1999) Collective action on common pool resource management: the contribution of a social constructivist perspective to existing theory. *Society and Natural Resources* **12**: 539–557.

Tang, S.Y. (1992) *Institutions and Collective Action: Self-Governance in Irrigation*. San Francisco, CA, USA: ICS Press.

Terborgh, J. (1999) *Requiem for Nature*. Washington, DC, USA: Island Press.

Trawick, P.B. (2001) Successfully governing the commons: principles of social organization in an Andean irrigation system. *Human Ecology* **29**(1): 1–25.

Tucker, C.M. (2008) *Changing Forests: Collective Action, Common Property, and Coffee in Honduras*. New York, NY, USA: Springer.

Walker, B. & Salt, D. (2006) *Resilience Thinking: Sustaining Ecosystems and People in a Changing World*. Washington, DC, USA: Island Press.

Webb, E. & Shivakoti, G.P., eds. (2008) *Decentralization, Forests and Rural Communities: Policy Outcomes in South and Southeast Asia*. New Delhi, India: Sage India.

Weimer, D.L. & Vining, A.R. (2005) *Policy Analysis: Concepts and Practice*. 4th edition. Upper Saddle River, NJ, USA: Prentice Hall.

Western, D. & Wright, R.M. (1994) The background to community-based conservation. In: *Natural Connections: Perspectives in Community-Based Conservation*, ed. D. Western & R.M. Wright, pp. 1–14. Washington, DC, USA: Island Press.

Wollenberg, E., Merino, L., Agrawal, A. & Ostrom, E. (2007) Fourteen years of monitoring community-managed forests: learning from IFRI's experience. *International Forestry Review* **9**(2): 670–684.

Young, O. (2002) *The Institutional Dimensions of Environmental Change: Fit, Interplay, and Scale*. Cambridge, MA, USA: MIT Press.