W11-6 7/10/11
DRAFT version 5.0

SES Framework: Initial Changes and Continuing Challenges

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Prepared for inclusion in Special Issue of *Ecology and Society*

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ABSTRACT

This paper updates a general framework for the study of social-ecological systems that was initially proposed in "A Diagnostic Approach for Going Beyond Panaceas" (Ostrom 2007). This SES framework has inspired much of the specific research reported on elsewhere in this special issue. The initial changes introduced in this paper have emerged from continuing interactions among a growing network of collaborators. Several more substantial directions for modification are briefly discussed, some of which are exemplified in the other contributions to this special issue.

Acknowledgments

The research which is foundational for this paper has been supported by the National Science Foundation, a subcontract with Dr. Thomas Sterner, University of Gothenburg, Sweden, that is funded by FORMAS, and the Workshop in Political Theory and Policy Analysis. We are deeply appreciative of the comments made by Michael Cox, Joshua Cinner, Thomas Falk, and Andreas Thiel on earlier drafts of our paper.

Keywords

Social-ecological systems, frameworks, institutional analysis, governance

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Most of the authors of articles in this special issue have been working together since the publication of "A Diagnostic Approach for Going Beyond Panaceas" (Ostrom 2007) to build on and improve the Social-Ecological System (SES) framework initially proposed therein. After briefly summarizing the ambition that lay behind that effort, this paper provides an overview of the initial changes that have been made to this framework as a consequence of continuing interactions among members of a still-growing network of collaborators. We also raise some issues concerning issues of learning and governance systems that remain unresolved at this time. The final paper in this volume revisits these issues, as well as other aspects of the diverse papers included here.

Readers should be warned that the framework developed here is *complicated*, as an early commenter put it politely. However, we are convinced that it is essential to first establish a common conceptual language if we are to glean general lessons from a growing number of empirical investigations of particular examples of the specific institutional arrangements used by community user groups (and other entities) in the management of diverse kinds of natural and technological resources in all regions of the world.

INSPIRATION BEHIND THE SES FRAMEWORK

Now that increasing numbers of scholars are interested in sustainability of social-ecological systems (SESs), the problem of how to provide a coherent analysis of complex, nested systems operating at multiple scales becomes ever more challenging. The disciplines at the forefront of

SES research (ecology, political science, geography, economics) have evolved over time and each has developed its own technical languages. If one is addressing how multiple forms of governance influence sets of resource users of various scales and background and how they impact on resource systems that have diverse characteristics, one needs to draw on multiple scientific disciplines to address such questions. One cannot just pick up any single disciplinary language system and apply it to a new problem. Frequently, the definition of terms in one discipline's language differs from those of another discipline, such as the meaning of community in ecology as contrasted to sociology.

Since SESs are inherently complex, theory is needed to guide the selection of an effective analytical focus. Yet no *one* theoretical perspective is sufficient to analyze all feasible situations. Hence, we need a framework for analysis that can help begin the process of organizing our understanding of the factors that may be relevant to an explanation of a particular phenomenon.

Initial discussion of the SES framework identified several priorities guiding its development. The basic idea was to develop an organizing framework that would enable researchers from diverse disciplinary backgrounds working on different resource sectors to share a common vocabulary and a logical linguistic structure for classifying those factors deemed to be important influences on the types of SESs of most interest to them. This common language would enable productive comparisons to be drawn across disparate geographic areas and temporal domains. It would also provide the basis for subsequent efforts to comparatively test theories focusing on different levels of aggregation.

This language framework was intended to remain "theory-neutral" so that competing hypotheses from alternative theoretical perspectives could be evaluated on a common basis. Finally, this exercise could serve the important purpose of identifying gaps in the existing literature, and especially gaps in existing datasets, and thereby provide compelling evidence that could be used to support applications for external funding.

The hope was that such a conceptual framework could, eventually, provide the foundation for establishing a diagnostic procedure through which institutional analysts could discern the most difficult problems facing stakeholders in a given set of circumstances. The remainder of this section explains what we mean by a framework, and why we think its establishment can be such an important advance on the current state of affairs.

Frameworks, theories, and models

A puzzle for many scholars is the difference between frameworks, theories, and models. The three terms are casually used almost interchangeably by scholars coming from different background. Here we draw upon a well-established distinction among framework, theory, and model. A "framework" provides the concepts and terms that may be used to construct the kinds of causal explanations expected of a "theory." A "theory" posits casual relationships among core variables, while a "model" constitutes a more specific manifestation of a general theoretic explanation in terms of the values of specific variables and functional relationships. Just as different models can be used to represent different aspects of a given theory, different theoretical explanations can be built upon a common conceptual framework.

Basically, frameworks, theories, and models are nested concepts related to explaining interactions and outcomes in a SES. Analyses conducted at each level provide different degrees of specificity related to a particular problem. Colleagues contributing to this special issue have used all three concepts in efforts to analyze SES processes and outcomes. In this section we define the three types of theoretical analysis, how they relate to one another, and how they differ.

The development and use of a general framework helps to identify the working parts and relationships among these elements that one needs to consider when studying SESs. Frameworks organize diagnostic, descriptive, and prescriptive inquiry. They provide the most general list of relevant concepts that can be used to analyze all types of SESs ranging from Wisconsin lakes (Brock and Carpenter 2007) to the Planet Earth (Rockström et al. 2009). Frameworks provide a meta-theoretical language that can be used to compare theories. They attempt to identify the universal elements that any theory relevant to the same kind of phenomena would need to include. Many differences result from the way these variables combine with or interact with one another (but one uses theory to predict outcomes of these relationships). Thus, the elements contained in a framework are the basic concepts that all scholars interested in the same general phenomena need but if they comes from diverse disciplines, how the concepts are defined and ontologically linked may differ substantially. Investment in updating and improving an interdisciplinary framework can provide an essential scientific dictionary for core concepts and their sub-concepts so that scholars trained diversely can work effectively together.

The development and use of theories enable analysts to specify which elements of a framework are particularly relevant to certain kinds of questions and to make general working assumptions about these elements and their relationships. Theories select for further analysis a subset of variables in a framework and make specific assumptions that are necessary for an analyst to diagnose a phenomenon, explain processes, and predict outcomes. Several theories are usually compatible with any framework. Diverse ecological and evolutionary theories as multiple social theories (game theory, transaction cost theory, social choice theory, covenantal theory, and theories of public goods and common-pool resources) are all compatible with the SES framework discussed in this special issue.

The development and use of models make precise assumptions about a limited set of parameters and variables. Logic and mathematics as well as simulation and lab experiments are used to explore systematically the consequences of these assumptions in a limited set of outcomes. Multiple models are compatible with most theories. An effort to understand the strategic structure of the games that irrigators play in differently organized irrigation systems, for example, developed four families of models just to begin to explore the likely consequences of different institutional and physical combinations relevant to understanding how successful farmer organizations arranged for monitoring and sanctioning activities (Weissing and Ostrom 1993). This is one of the models we have developed for the precise analysis of a subpart of the theory of common-pool resources.

A number of scholars have asked why we need a framework. Isn't a theory enough? One response relates to the number of diverse processes occurring in SESs. If one is interested in understanding processes of use, maintenance, regeneration, and destruction of natural resources or humanly constructed infrastructures, then one is actually interested in a wide diversity of *different* processes going on either simultaneously or sequentially. One can have broad theories about the diversity of processes going on in such systems, but if scholars work independently on a theoretical explanation for one type of phenomenon, those interested in related phenomena may not understand how work by one scholarly approach is related to theirs.

For policymakers and scholars interested in issues related to SESs a framework helps to organize diagnostic, analytical, and prescriptive capabilities. It also aids in the accumulation of knowledge from empirical studies and in the assessment of past efforts at reforms. Markets and hierarchies are frequently presented as fundamentally different "pure types" of organization. Not only are these types of institutional arrangements perceived to be different, but each is presumed to require its own explanatory theory. Scholars who attempt to explain behavior within markets use microeconomic theory, whereas scholars who attempt to explain behavior within hierarchies use political and sociological theory. Such a view precludes a more general explanatory framework and closely related theories that help analysts make cross-institutional comparisons and evaluations.

Connecting the IAD and SES frameworks

For a number of years, colleagues associated with the Workshop in Political Theory and Policy Analysis have attempted to cope with the complexity inherent in policy analysis by the development of the Institutional Analysis and Development (IAD) framework. In the past three decades since the first publication of that framework (Kiser and Ostrom 1982), substantial progress has been made, particularly related to the governance of diverse systems and concepts of strategies, rules, norms, and other key institutional terms (see McGinnis 2000, 2011a, Ostrom 2005, 2011, Poteete et al. 2010).

In the extensive work on urban governance, on groundwater, on irrigation systems as well as on forestry resources, we have found that using the IAD framework for our micro-analysis of the diverse, problematic situations that individuals find themselves in has been extraordinarily productive (Blomquist and deLeon 2011, Bushouse 2011, Heikkila et al. 2011, Oakerson and Parks 2011, Ostrom 2011). It is certainly possible to do a game theoretic analysis of the harvesting decisions that individual appropriators from a common-pool resource may engage in when there are no property rights and no informal agreements. A core question of considerable interest is when will the participants cooperate and when will they invest in organizing themselves for longer term governance and protection of a resource system? As soon as one gets into the wide diversity of puzzles and paradoxes related to governance, one no longer is coping with just a single theory of collective action (or collective inaction).

It is possible to do a formal theory of the costs and benefits of self-organization for the actors involved in a common-pool resource problem (see the SOM for Ostrom 2009). The number of variables that potentially affect the costs and benefits to diverse participants in a process is rather large, however, and it is difficult to get accurate measures of perceived benefits and costs for those involved. When people are in a market situation and they face market prices as benefits and costs, it is a lot easier to calculate net benefit cost ratios than when we are dealing with public goods or common-pool resources.

This is where a framework is particularly useful because one can slowly but surely identify a variety of factors about the resource system, the resource units, the actors involved, and the governance system that impact on initial self-organization. In a recent study of three communities in Mexico, Basurto and Ostrom (2009) were able to assign a 3 level measure (low, medium and high) to the variables posited in general to affect self-organization in an SES and to help explain why two of the communities did self-organize to manage their fishery and the third did not. That is an illustration of the framework and how it can be used. Our International Forestry Resources and Institutions (IFRI) research program and data base also give us the chance of addressing multiple questions over time (Wollenberg et al. 2007). The SES framework grew out of our own efforts to identify relevant variables as well as those identified by many scholars in diverse fields. Thus, a framework is useful for identifying potentially relevant general knowledge and the general sweep. While a theory begins to identify how parts of that are linked, a model is a way of being very formal in the way you represent that.

At the heart of the IAD framework is the “action situation” in which individuals (acting on their own or as agents of formal organizations) interact with each other and thereby jointly affect outcomes that are differentially valued by those actors. The IAD framework highlights the social-cultural, institutional, and biophysical context within which all such decisions are made. Specifically, this framework helps organize the task confronting a scholar or policy analyst approaching a policy issue by directing their attention to (1) the rules-in-use, rather than the rules on paper, (2) the underlying biophysical nature of the good under consideration, in terms of it being a private, public, or toll/club good or a common-pool resource (CPR), as well as (3) the most relevant attributes of the community, especially ambient levels of trust and shared norms of reciprocity.

The IAD framework was based on a dynamic view of policy processes. Social, institutional, and biophysical factors were seen as inputs to a process of decisions made by individuals (with those decisions presumed to be influenced by their pre-existing cognitive capabilities and cultural presuppositions), and these decisions were somehow aggregated to constitute policy outputs that would then interact with exogenous factors to produce some observable outcomes, and evaluations of these outcomes by these actors (or by other observers) would then feedback into all of the previous components of this never-ending process. In effect, the IAD framework was an extended elaboration on a basic systems model of policy processes.

Systems typically look very different depending on the level of aggregation being used, and that observation certainly applies to action situations. The IAD framework explicitly distinguishes three levels of analysis in which different types of choice processes take place: (1) at the operational level actors (either as individuals or as representatives of specific collective entities) make practical choices among their available options, as determined by (2) collective level choices involving the determination of which strategies, norms and rules are, should be, or are not available to actors fulfilling the specific roles defined by that group (as well as specifying who is assigned to fill these roles); and (3) constitutional level choices relating to who is or should be empowered to participate in the making of collective and operational level decisions. Rules that define and constrain the operational activities of individual citizens and officials were established by collective choice processes, and the rules by which these rules themselves are subject to modification are determined through a process of constitutional choice. The critical insight behind this framework is that the outcomes of interactions in different levels of analysis are explicitly connected to each other.

The actors in any action situation are presumed to be boundedly rational. They seek to achieve goals for themselves and for the communities to which they identify but do so within the context of ubiquitous social dilemmas and biophysical constraints, as well as cognitive limitations and cultural predispositions. Within this broad framework a range of theoretical perspectives may be employed to develop and analyze models of specific situations.

As Workshop scholars began to work more intensively with ecologists, we repeatedly heard the criticism of the IAD framework as not taking concepts of relevance to ecologists as seriously as we were taking diverse levels of concepts related to institutions. This criticism certainly had some merit. Consequently, we began several years ago to slowly expand the original IAD framework to encompass a broader set of variables that are needed for the analysis of a SES. Since the publication of the first version of the SES framework (Ostrom 2007), there has been considerable interest by scholars across a wide diversity of disciplines in that approach. In 2009, a revision was published in *Science* (Ostrom 2009) and still more interest has accumulated (see for example, Gutiérrez et al. 2011). In this article, we examine how these reactions have already led to improvements in the SES framework. The last article in this Special Issue will provide an updated version of the SES framework in light of the research undertaken over the past year and presented by the contributors to this special issue.

INITIAL REACTIONS AND SLIGHT MODIFICATIONS

The SES framework was originally designed for application to a relatively well-defined domain of common-pool resource management situations, in which *resource users* extract *resource units* from a *resource system*, and provide for the maintenance of that system, according to rules and procedures determined by an overarching *governance system*, and in the context of *related ecological systems* and *broader social-political-economic settings*. The processes of extraction and maintenance were identified as among the most important forms of *interactions and outcomes* that were located in the very center of this framework, as illustrated in slightly different forms in two articles by Elinor Ostrom (2007, 2009).

Key attributes of each of these components were identified as second-tier variables or explanatory factors and allowance was made for the potential relevance of more detailed variables or empirical indicators located at lower tiers in this ontological framework. We use the term "tier" to denote different logical categories, with lower level tiers constituting subdivisions within elements from the next higher tier. Thus, for example, Resource System denotes a top-tier category with second-tier subdivisions denoting such characteristics as its size, type of resource sector, clarity of resource boundaries, etc. In turn, each of the entries in the second tier have characteristics that can be identified at the third tier. To continue this example, size may be denoted in terms of geographic expanse, number of species interacting within that system, etc. Our intentions is that this framework could serve as a guide to researchers seeking to investigate questions concerning the initial establishment or sustainability of a particular configuration of patterns of interactions and outcome experienced within a tightly coupled SES. From the several empirical applications that have already been implemented, we are beginning to draw lessons about which aspects of initial framework should be revised to facilitate subsequent applications, and, especially, communication across disciplinary, geographic, and resource sector boundaries.

As others begun to react to the initial statement of the SES framework, several argued that this framework was potentially broader in scope than we originally claimed. In particular, there seemed no compelling reason to restrict attention to common-pool resources, since many social-ecological systems encompass goods and services that are better described as private, public, or toll goods.

In this section we specify a few minor modifications that emerged from a series of interactions among colleagues who have participated in a series of meetings to discuss and build on the foundation of the SES framework. We have called ourselves the SES Club (see E. Ostrom, this Special Issue for a brief history of the SES Club). Each of these modifications moves the framework in the direction of increased generality. Later sections in this paper, as well as other papers in this issue, discuss more substantial modifications that are currently under consideration.

Recognition of action situations

The IAD framework attached prominence to the concept of an action situation – in which actors in positions made decisions about actions in light of the information they had about the likely actions of other participants and the benefits and costs of likely outcomes. The initial versions of the SES diagnostic framework (Ostrom, 2007, 2009) implicitly incorporated the action situation in the link between interactions and outcomes. Initial feedback on these versions of the SES framework suggested that the action situation needed to be explicitly incorporated. Accordingly, Ostrom (2010) used the occasion of her Nobel Prize acceptance speech to change the label of the Interactions and Outcomes box to also include the broader term -- Action Situation. This simple step cemented a close connection between decades of work on the IAD framework and the newly established SES framework.

Generalizing users to actors

The SES framework drew the attention of researchers investigating diverse types of resources, including several studying highly technical systems of infrastructure networks. For such applications some aspects of the original framework did not seem directly relevant, including such key terms as “resource units” or “users.” In a meeting held in Delft in May 2010 participants agreed that the category “Actors” was more inclusive than “Users” and this change was recommended for any future application. As noted in the paper by Hinkel et al. in this issue, Users is now treated as a sub-category of the more general category of Actor.

Another important clarification is that some of these actors may be collective entities. The possibility that some formal organizations are so organized as to make them effectively act as if they were unitary actors cannot be precluded at this level of a framework. Those using certain theoretical perspectives may prefer to strictly avoid anthropomorphizing collective entities, but under other theoretical perspectives this is a reasonable procedure for specific analyses.

Multiple versions of top-tier components

One important clarification that has emerged in these discussions is that some applications may require specifying a set of interrelated action situations as well as multiple instances of the entity classes. The analysis of focal systems involving irrigation systems, for example, requires analysis of at least two action situations: one that focuses on how the physical system is maintained and a second that focuses on water distribution. Further, there may be two related resource systems: surface water and groundwater. This recognition has led to a major revision of the framework, in which each of these first-tier components are allowed to exist in multiple versions in any given application. Allowing for the simultaneous operation of several action situations is useful for representing complex systems. McGinnis (2011b) defines action situations as adjacent to each other when outcomes generated in one action situation affect a structural attribute or affect the rules under which interactions occur within the other action situation. He uses this notion of adjacency to build networks of action situations and illustrates this concept with examples from three distinct policy areas. In his analysis adjacent action situations are linked through changes in their internal structures as well as flows of material, financial, or informational resources. Cox (this issue) uses this concept to structure and improve his analysis of acequia SES in New Mexico.

Initially the SES framework was presented as if the focal action situation involved only one set of users, inhabiting one overarching governance system, who were dependent on a particular type of resource unit, which were in turn extracted from a particular resource system. The possibility of multiple governance settings or ecosystems was incorporated in the S and ECO categories located outside of the focal box. However, the initial figures made it appear as if the framework allowed only one instance of each of the first-tier components.

We now prefer to use a representation that explicitly allows for the coexistence of multiple instances of each of the top-tier components (Figure 1). In practical examples, some researchers identified more than one resource system, or more than one relevant resource unit, as well as multiple user groups. For example, in his analysis of *acequias*, Cox (this issue) treats a network of irrigation canals and infrastructure and an underlying set of shallow aquifers as two separate subcomponents of the overall resource system.

After considering several alternative formulations, we have decided to treat each instance of a single category as an element of the set of potential empirical referents of that conceptual category. To continue with the *acequias* example, each network of interconnected irrigation canals and each aquifer can be treated as an instance of the Resource System category. For some applications it may be useful to aggregate all aquifers into a single resource system, but for other purposes it is useful to consider them separately. For some resource questions, it might be more appropriate to treat the entire irrigation-aquifer system as a single integrated water resources system or the watershed of the river as a whole. On the social side, it may also be desirable to treat the river valley as a single integrated community for some research questions, while other circumstances will require consideration of each tribal community or political jurisdiction as separate entities.

In sum, the same set of second and lower tier factors are potentially relevant for application to resource or social entities located at different levels of aggregation. No matter what level of aggregation a researcher finds most appropriate for a given investigation, the SES framework provides what we hope can become an exhaustive ordering of all potentially relevant explanatory factors.

Broadening the Meaning of Resources

Some colleagues have been eager to see us allow for a broader interpretation of the resource side of a social-ecological system. Specifically, some expressed a strong interest in being able to apply a similar mode of analysis to understand management of an artificially constructed technological system, such as a power grid or telecommunications system. It is not automatically clear whether or not the SES framework can be usefully applied to the study of what might be called social-technical systems.

One consequence of this discussion was our decision to change the name of the Resource Units (RU) first-tier category to the more inclusive category of Resource Services and Units (RSU). After all, some important resources can be consumed even though it may not be easy to carve that resource or service into distinct units. This is especially true for such public goods as the ecosystem services that have become more widely recognized by policy experts in recent years. This incorporation of non-discrete services is especially important for applications to constructed social-technical systems.

After re-examining the initial labels assigned to the second-tier factors under the initial RU category, we decided that RU6 (Distinctive Markings) should be replaced by RSU6 (Distinctive Characteristics). Although markings make sense for application to such tangible resources as animals, that term does not seem appropriate for the case of electricity or a portion of the electromagnetic spectrum. Further, other characteristics of living entities identified by behavioral ecology – such as the breeding season and locations – frequently affect the outcomes of action situations.

Another minor change to the framework emerged from this allowance for the consumption of non-discrete resource services. We decided to add another second-tier characteristic (RSU8) to designate the Divisibility (or discreteness) of the resource services or units under question. This characteristic strikes us as being sufficiently different from the mere number of units (RSU1) to merit separate consideration.

Künneke and Finger (this issue) propose a way to explicitly extend the SES framework to incorporate complex infrastructure systems. From one perspective, human-constructed facilities were already included in the initial formulation as part of the resource system category (RS4), but we welcome their effort to explicitly demonstrate how the SES framework might be adjusted to be more appropriate for application to Social-Technical Systems (STS).

At an earlier juncture we considered interpreting a social-technical system as being composed of two logically separable components, focused respectively on production and consumption of the constructed technical resource. Our idea was that the production and consumptions side could be subject to separate analysis via the SES framework. On the production side, infrastructure producers draw resource inputs from natural resource systems and construct a technical infrastructure. This side seems a straightforward representation of the SES as currently established. On the consumption side, individual (or corporate) actors draw resources from a humanly-constructed technical system.

Ultimately, however, we were convinced that the ideas developed by Künneke and Finger were a more promising path of conceptual development. Any effort to maintain a strict distinction between naturally occurring and artificially constructed social-ecological systems eventually breaks down, given the variety of ways in which human actions have shaped the natural environment. Even so, these thoughts about the potential utility of separating production and consumption into separate processes for analytical convenience helped inspire another means of allowing for the analysis of interactions among the many functions that might be fulfilled by different aspects of a complex SES.

Differentiating among diverse relationships

Allowing for multiple instances of each of the top-tier concepts highlighted another issue that soon arose in discussions regarding this framework. Some colleagues noted that it was effectively an ontology, in the sense that it defined a language of terms and specified a series of logical relationships among these terms. As we attempted to elaborate this underlying logical structure as a formal ontology, it soon became clear that these categories were linked together in more than one way. As a consequence, we have become more explicit in the nature of the relationships posited between components of the SES framework.

This topic is covered in detail in Hinkel et al. (this issue), so we can be brief here. Some relationships are compositional in form, such as the actors who are jointly influenced by the operation of a particular governance system, or the resource units that comprise a larger resource system. Other factors identified in the SES framework are attributes attached to instances of that class of entities, such as the number of actors involved in harvesting activities, or the physical extent of the resource system under consideration. Still other attributes must be associated to aggregations of units, or refer to properties that emerge at higher levels of aggregation. Finally, instances of different governance systems may interact with each other, and with other top-tier components, in a wide variety of ways. These interactions can be interpreted as instances of the action situation component, and may involve a large number of instances from one, two, three or all four of the primary top-tier components (actors, governance systems, resources systems, and resource units).

Another logical relationship that has emerged more clearly from the Hinkel et al. formulation concerns interactions between the aspects of a given SES observed at different points in time. As they demonstrate, the factors listed in the figures are best interpreted as parameters and state variables in place at a given point in time. Outcomes of action situations at one point in time may influence the values of that same system in effect at later times. This form of feedback closely resembles the feedback paths that were explicitly included in the initial formulation of the IAD framework. Although some feedback paths were included in the initial figures representing the SES framework, we now realize that it is necessary to develop a clearer statement of the dynamic formulation implicit in this framework. We return to this question in a later section.

AN UPDATED FIGURE

All of the modifications discussed above are incorporated into Figure 1. As in Ostrom (2010), action situations, interactions, and outcomes are included in the same part of that figure. The User label has been replaced by the more general category of Actors, and Resource Units by Resources Services and Units.

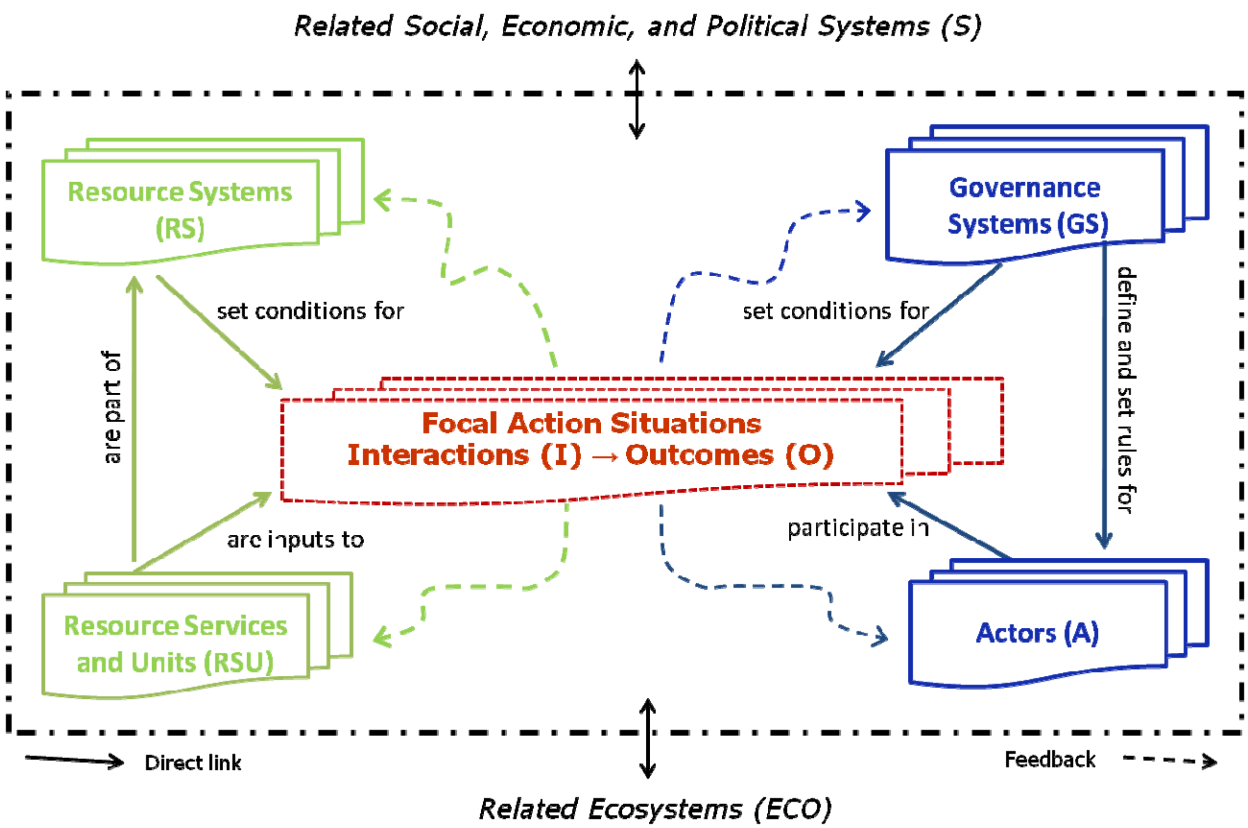

Figure 1. Revised SES Framework with Multiple First-Tier Components

In Figure 1, rectangular boxes are used to denote first-tier categories. The rectangles used for Resource Systems, Resource Services/Units, Governance Systems, and Actors are the highest tier variables that contain multiple variables at the second tier as well as at lower tiers. Action situations are where all the action takes place as inputs are transformed by the actions of multiple actors within them into outputs. The dotted-and-dashed line that surrounds the interior elements of the figure indicates that an SES can be considered as a logical whole but that exogenous influences from other ecological or social-economic-political systems may impact the SES at any point in that system.

There are multiple boxes for each sub-component to illustrate the potential for concurrent operation of multiple instances of each of these first-tier components. Labels are added to the direct links denoted by solid lines in this figure. This was done to highlight the different logical nature of these connections. For example, resource systems that are characterized by a diversity of attributes include resource services and physical units that can be consumed or extracted for use by actors. Any given governance system will have authority over some defined set of actors, and its outcomes may effectively define the nature of those actors and the options available to them. Whereas actors participate in action situations, resource units are better interpreted as inputs into the processes that take place there. Both governance systems and resource systems set the conditions under which action situations take place, specifically by determining the rule-in-use, attributes of the community, and the nature of the goods in question that play such a pivotal role in the IAD framework.

Social, Economic, and Political Settings (S)
S1- Economic development. S2- Demographic trends. S3- Political stability.
S4- Government resource policies. S5- Market incentives. S6- Media organization.

Resource Systems (RS)

RS1- Sector (e.g., water, forests, pasture, fish)
RS2- Clarity of system boundaries
RS3- Size of resource system
RS4- Human-constructed facilities
RS5- Productivity of system
RS6- Equilibrium properties
RS7- Predictability of system dynamics
RS8- Storage characteristics
RS9- Location

Governance Systems (GS)

GS1- Government organizations
GS2- Nongovernment organizations
GS3- Network structure
GS4- Property-rights systems
GS5- Operational rules
GS6- Collective-choice rules
GS7- Constitutional rules
GS8- Monitoring and sanctioning rules

Resource Services and Units (RSU)

RSU1- Resource unit mobility
RSU2- Growth or replacement rate
RSU3- Interaction among resource units
RSU4- Economic value
RSU5- Number of units
RSU6- Distinctive characteristics
RSU7- Spatial and temporal distribution

Actors (A)

A1- Number of actors
A2- Socioeconomic attributes of actors
A3- History of use
A4- Location
A5- Leadership/entrepreneurship
A6- Norms (trust-reciprocity)/social capital
A7- Knowledge of SES/mental models
A8- Importance of resource (dependence)
A9- Technology used

Action Situations: Interactions (I) → Outcomes (O)

I1- Harvesting levels
I2- Information sharing
I3- Deliberation processes
I4- Conflicts
I5- Investment activities
I6- Lobbying activities
I7- Self-organizing activities
I8- Networking activities
I9- Monitoring activities

O1- Social performance measures
(e.g., efficiency, equity, accountability, sustainability)
O2- Ecological performance measures
(e.g., overharvested, resilience, biodiversity, sustainability)
O3- Externalities to other SESs

Related Ecosystems (ECO)
ECO1- Climate patterns. ECO2- Pollution patterns. ECO3- Flows into and out of focal SES.

Figure 2. Second-Tier Variables of an SES

Figure 2 is an updated list of the second-tier variables included within each of the top-tier categories of Resource Systems, Resource Services and Units, Actors, Governance Systems, and Action Situations (Interactions and Outcomes). Their labels have been revised to reflect the specific changes detailed above. In addition, a few additional forms of interactions have been added to the original list. For example, the activities required for monitoring should be considered as forms of interaction that are logically distinct from the monitoring rules included under the Governance System category.

For future reference, Figures 1 and 2 incorporate the following changes from the versions presented in Ostrom (2007, 2009):

1. Changes in labels for first-tier categories:
    a. Actors (A) replaces Users (U);
    b. Resource Services and Units (RSU) for Resource Units (RU), and
    c. Action Situation added to label for Interactions and Outcomes.
2. Multiple instances of any of the first-tier categories may be included in an analysis of any particular application, and the SES allows for such multiplicity.
3. Figure 1 includes labels summarizing the logical relationships between first-tier categories.
4. RSU6 (Distinctive Characteristics) substituted for RU6 (Distinctive Markings).
5. RSU8 (Divisibility) added to the second-tier for RSU, to allow for services that cannot be divided into distinct units.
6. Monitoring activities are included as a particular instance of the Action Situation category.

Briefly, all these changes were made in the interests of generalizability, by extending the SES Framework to apply to complex social-ecological systems in which multiple sets of actors consume diverse resource services or units extracted from multiple interacting resource systems in the context of overlapping governance systems, as well as making it possible to use the same framework to examine social-technical systems in which the resources involved are explicitly constructed by human action.

These two updated figures summarize the framework as it was understood by authors of the studies reported in this Special Feature. As our colleagues discuss elsewhere in this issue, we are certain that there will be further modifications as empirical and theoretical advancements are made in SES studies. Indeed, several of our colleagues report on significant advances in this same issue and the last article in this special issue makes one further update in light of the findings presented herein. As we discuss in that paper, that version will be defined as the initial version of the electronic repository of the SES framework that the SES Club will collectively maintain. From this point forward, a wiki will be used to maintain records of any subsequent modifications to the SES framework.

CONTINUING CHALLENGES

In this section, we briefly discuss two aspects of the SES framework that continue to puzzle us. Given the ambitious reach of our goals, it should not be surprising that our efforts to encompass so much within a single framework has generated some conceptual issues that are not easy to resolve. Here we discuss two issues that we consider to be critically important for the future development of this mode of analysis, specifically the nature of governance institutions and processes of individual and collective learning.

Governance institutions and systems

Of the four primary top-tier SES components, the initial list of factors for Governance Systems now seems the least compelling. The more we have worked with the SES framework, the more selection of those particular sub-categories seems to have been guided by a different logic than the others. However, we also realize that others have used these categories to organize their own analysis of particular resource sectors. Furthermore, in this issue, Hinkel et al. have defined a procedure intended to guide future modifications to the SES framework. So, at this time the most we can say is that we would expect the implementation of this procedure will most likely result in some significant changes in this particular category.

In hopes of triggering further investigation, we offer the following tentative list of potential second-tier (and selected third-tier) factors under the Governance System category.

GS1—Rule-Making Organizations
- Government organizations
- Nongovernmental organizations
- Private organizations
- Community-based organizations
- Hybrid organizations

GS2—Informal procedures
GS3—Networks
GS4—Legal systems
GS5—Rules in Use
- Operational-choice rules
- Collective-choice rules
- Constitutional-choice rules

GS7—Policy Tools/Instruments

Our logic in developing this list is the following. To begin with, we downgrade the government and nongovernmental organization categories to the third tier, under a broader category of rule-making organizations. This move enables us to add other types of organizations active in governance, specifically private corporations, community-based organizations, and hybrid organizational forms that combine aspects of public, private, or voluntary structures. To complement the category of formal organizations, we next allow for the impact of informal processes of coordination, in which otherwise incoherent groups may act jointly, at least in some circumstances. We also include the important institutional forms of networks and legal systems.

In this tentative list we also downgrade the operational, collective, and constitutional rule categories to serve as sub-categories of a broader category of the rules-in-use in a given situation. The monitoring and sanctioning rules included in the original formulation might be even further downgraded to the status of instances of certain types of rules at one or more of these levels. In addition, monitoring and sanctioning activities can be added to the list of interactions included in the action situation category. Given the importance attached to these kinds of activities in many sustainable systems of resource governance, it is worth distinguishing the rules as promulgated or otherwise established at the level of the governance system from their actual implementation in action situations.

Each of the rules in these categories can be represented in the form of the ADICO grammar of institutions developed by Crawford and Ostrom (1995). We could also add categories for policy instruments and for attributes that might be attached to a governance system as a whole. These steps are being explored by Cox and Frey (2011). Although we can imagine other potentially relevant factors, we stop at this point, since this list is only meant to be suggestive and to inspire subsequent investigation.

Learning

Learning is perhaps one of the most important processes that occur within and across action situations. Although we are convinced that learning has an important connection to the category of Action Situations, we also think that there is not an immediate straightforward way of incorporating learning as a second-tier attribute. One of the puzzles regarding learning is whether it is an interaction or an outcome. Deliberative activities, included as a second-tier characteristic of action situations (I3), clearly constitute interactions– actors are engaged in discussions about what they are doing, the goals they should pursue, what strategies, etc. But learning is something more fundamental, since it plays such a critical role in the temporal connection between an SES at time 1 and its successor at t+1.

Our perplexity arises from continuing differences across disciplines. If you assume complete information (as in classic micro-economics), then learning is not considered a distinct process and as a consequence does not play any significant role in most economic analyses. Conversely, for scholars from psychology or cognitive science, learning is one of the core processes that they are trying to explain.

Another complication is that learning can occur on multiple time scales. Individuals learn during their lives, and language allows them to convey knowledge to contemporaries and to later generations. At the organizational level, new understandings can be incorporated within the set of decision procedures being implemented by members of that organization. Societies can also be said to learn, in the sense that traditions change over time, through a complex process of adaptation to new circumstances. In addition, information can be lost over time, and may have to be rediscovered by later generations.

Ecologists and others who study systems which exhibit complex dynamics are particularly sensitive to the concurrent operation of dynamic processes operating at different time scales. Direct feedback can be immediate, whereas other feedback paths can be indirect and time-consuming. Complex systems can adapt over time, and may change dramatically when they cross thresholds that may not be apparent to observers at the time of transition. Given the complex dynamics of systems including multiple feedback paths, the researcher must carefully specify the time frame considered relevant for explaining outcomes.

Pahl-Wostl (2009; this issue) has articulated a similarly complex view of learning dynamics, specifically by differentiating among first, second, and third levels of learning loops.

In the first loop, actors revise their strategies in light of the consequences they observe. Over a longer time frame, these mechanisms of observation and updating may be incorporated into the collective processes that guide selection of these strategies. In the third loop, organizational structures may be fundamentally transformed into learning organizations, optimized to make effective use of available information on a timely basis.

These three loops roughly correspond to the levels of analysis in the IAD framework. The first type of learning should be routine in operational level interactions, whereas the second level of learning requires changes in the procedures through which collective policy decisions are made. The more fundamental changes identified in the third loop could be related, within the IAD framework, to either the constitutional or meta-constitutional level (Ostrom 2005, McGinnis 2011a).

Elsewhere, Pahl-Wostl (2009) posits explicit connections between generic stages of a policy process and specific action situations she identifies in her analysis of water management processes. In the dynamic models constructed on the basis of her MTF framework, action situations generate outputs in the form of flows of operational resources, knowledge, or institutional changes. This dynamic logic seems quite congruent with the intentions behind the SES framework, since the outcomes of many actions situations will change the values of several variables in the SES as measured at times t and t+1, thus serving as the analytical link between the static variables listed in the other first-tier headings. However, it is not apparent how this connection might best be formalized.

In a chapter entitled Animating Institutional Analysis, Ostrom (2005) highlights the importance of a more careful specification of the processes through which actors learn new norms and decision heuristics. Poteete et al. (2010) summarize subsequent research demonstrating the critical importance of micro-situational variables on the ability of groups to develop the levels of trust and capacities for learning required for sustainable collection action. But trust is not something that can be "created" on demand, as it takes time to be established and recognized as such.

Our problem is that we are not quite sure where these feedback paths and learning process should be located within the SES framework. Single or even double loop learning might be incorporated within action situations at the appropriate level, but triple loop learning seems too long-term to be conceptualized as occurring within a single action situation. More generally, we are concerned that dynamic feedback paths do not fit easily into the SES framework as we have defined it thus far. Other contributors to this volume raise related issues, including the final paper's suggestions concerning some possible ways forward.

CONCLUSION

In conclusion, we return to the original inspiration behind the SES framework, namely, to develop diagnostic tools for potential use by scholars studying social-ecological systems. Diagnosis is a routine activity of medical professionals, and it plays an absolutely critical role in healthcare, but it is not immediately obvious what the appropriate analogy would be for the activities of social or ecological researchers.

Medical professionals ask questions about an individual's symptoms in order to ascertain the nature of the underlying health problem that individual faces. Medical textbooks include incredible amounts of detail, only some of which is relevant to particular diagnoses or treatments. Making the proper diagnosis is an essential step towards effective treatment. This process of diagnosis cannot be automated, but instead requires trained professionals to draw upon their organized understanding of the relevant fields of scientific study.

The SES framework offered here is intended to provide institutional analysts with the foundation for a similar form of organization for the knowledge relevant to the diagnosis of the properties of specific social-ecological systems. Ultimately, we hope a more fully elaborated framework can serve as a useful guide for analysts seeking to enhance the prospects of effective and sustainable outcomes. If nothing else, such a framework can contribute by prompting analysts to ask certain types of questions and to investigate certain aspects of any given situation.

Application of the SES framework to particular cases requires at least a three-step process, with each step corresponding to the framework, theory, and model distinctions identified above. In the first step, the analyst must select a focal level of analysis, by answering such questions as: What types of interactions and outcomes related to a particular resource system (or group of systems) and related resource services and units are most relevant to my analytical or diagnostic concerns? What types of actors are involved? Which governance systems influence the behavior of these actors?

Answers to these questions will specify the actors, resource services and units, resource systems, and governance systems that the analyst will need to investigate in more detail. Examination of the framework will prompt the analyst to search for certain kinds of information, but without any additional guidance, any effort to fill in values of all of the possibly relevant variables identified at the second and lower tiers could turn out to be an endless undertaking.

For any practical results, analysts must also draw upon their theoretical understanding of the issue at hand. Theory, augmented by puzzles from past research that are not yet reconciled in a consistent theory, must guide the selection of which variables are likely to be most important in that particular setting. Of course, alternative theories may suggest the importance of different variables, but no reasonably small set of theories can exhaust all the potential entries in the framework. Even within a single theory, specific models will posit different functional relationships or causal pathways, and the analyst must choose which alternative explanations are most deserving of his or her attention. Here is where the critical concerns of research design become most important, as the analyst selects which cases and what kinds of observations of these cases can best provide the analytical leverage needed to be able to draw valid inferences from this particular research project.

In other words, application of the SES framework constitutes only the first step in the process of research. Much remains to be done to select which variables should be measured, and how these indicators can be defined and implemented, but the framework can help a research team feel confident that they have not overlooked some potentially critical factor.

After the analysis is completed, the framework can make still another critical contribution, by facilitating the communication of results across research communities focusing on different resource sectors in separate geographic regions, using the analytical lens of diverse disciplinary specializations. The specific meaning of each concept or the particular indicators used to measure them may differ considerably when moving from one empirical setting to another, but the first and second tier categories should remain equally relevant to all applications. Having this common base of shared terms increases the chances that cumulative progress can be made, making it easier for researchers trained in different disciplines and studying different resources in different places to compare their findings, and to engage in mutually beneficial exchanges of information.

We recognize that there are many challenges to be faced in the future as we try to make this a really useful tool helping scholars from multiple disciplines to use a common language for future theoretical and research efforts. A complete representation of dynamic linkages among concurrent action situations operating in complex SESs remains a distant goal, but the modifications discussed here point in promising directions for subsequent research. In addition, the empirical articles in this special issue demonstrate how much we can learn from efforts to apply this general framework to the analysis of particular cases. In each instance, new aspects take on increased importance, even as lessons are drawn from applications of similar concepts to quite different ecological settings. All this work is very exciting, and we can only hope that the SES framework continues to inspire such high-quality research, and especially that it can facilitate communication among scholars from a broad array of disciplines working on diverse resources in many different parts of the world.

At the Workshop, we are developing careful definitions for all major first and second tier concepts identified in the current version of the SES framework which we will place on the SES website and encourage other scholars to help us improve these. We will also develop a Protégé tool for identifying the levels of variables currently used in our very large IFRI database to share with other scholars. We consider further refinement of the SES framework to be one of the major ongoing efforts at the Workshop.

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