Lecture I. Frameworks
Lecture II. Analyzing One-Hundred-Year-Old Irrigation Puzzles

ELINOR OSTROM

The Tanner Lectures on Human Values

Delivered at

Stanford University
February 16–18, 2011

ELINOR OSTROM is Distinguished Professor, Arthur F. Bentley Professor of Political Science, and Senior Research Director of the Workshop in Political Theory and Policy Analysis, Indiana University, Bloomington; and Founding Director, Center for the Study of Institutional Diversity, Arizona State University. She is a member of the American Academy of Arts and Sciences, the National Academy of Sciences, and the American Philosophical Society, and a recipient of the Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel 2009, Reimar Lüst Award for International Scholarly and Cultural Exchange, Elazar Distinguished Federalism Scholar Award, Frank E. Seidman Distinguished Award in Political Economy, Johan Skytte Prize in Political Science, Atlas Economic Research Foundation's Lifetime Achievement Award, and John J. Carty Award for the Advancement of Science. Her books include *Governing the Commons* (1990); *Rules, Games, and Common-Pool Resources* (1994, with Roy Gardner and James Walker); *Local Commons and Global Interdependence: Heterogeneity and Cooperation in Two Domains* (1995, with Robert Keohane); *Trust and Reciprocity: Interdisciplinary Lessons from Experimental Research* (2003, with James Walker); *The Commons in the New Millennium: Challenges and Adaptations* (2003, with Nives Dolšak); *The Samaritan's Dilemma: The Political Economy of Development Aid* (2005, with Clark Gibson, Krister Andersson, and Sujai Shivakumar); *Understanding Institutional Diversity* (2005); *Understanding Knowledge as a Commons: From Theory to Practice* (2007, with Charlotte Hess); *Working Together: Collective Action, the Commons, and Multiple Methods in Practice* (2010, with Amy Poteete and Marco Janssen); and *Improving Irrigation in Asia: Sustainable Performance of an Innovative Intervention in Nepal* (2011, with Wai Fung Lam, Prachanda Pradhan, and Ganesh Shivakoti).

LECTURE I.
FRAMEWORKS

ABSTRACT

Currently, scientific approaches to the study of sustainability of complex ecological systems and socioeconomic systems are quite disparate. Over time, biology and ecology have accepted the necessity of understanding complex systems in developing a nested, scientific language to study them. Many social scientists who focus on the question of sustainable markets or political systems have instead attempted to develop the simplest possible models and theories to explain what is occurring in the world over time. The biological and ecological sciences have been extremely successful in understanding ecological systems that are remote and, thus, not strongly affected by human action. When humans play a major role, however, both the biological sciences and the social sciences lack effective theories and explanations of failures as well as successes. This problem will not be solved in rapid order. One of the steps is the development of a shared language that links what is going on in regard to resource systems and resource units with what is going on in relationship to governance systems and actors as they jointly affect action situations, incentives, and outcomes. In this first Tanner Lecture, I review the development of a social-ecological framework that will hopefully facilitate cumulative learning across social and ecological sciences and, eventually, the development of better theories and models.

The tight, disciplinary boundaries between political science and economics have frequently been crossed, but not all colleagues in both disciplines approve of work in political economy. "We need our disciplines," they say. I am not antispecialization, but we need to figure out how to use our disciplinary, specialized knowledge collaboratively and find a broader language that will allow us to communicate "across the divide." The divide within the social sciences is rather deep, but when we address policies related to ecological systems, we need to understand concepts that have been developed within both the social and the ecological sciences and how they relate to each other.

One approach—but not the only one—that colleagues at the Workshop in Political Theory and Policy Analysis at Indiana University as well as at many universities in the United States and Europe have struggled with is how to build a common framework and use it to conduct research related to the performance of Social-Ecological Systems (SESs). Instead of looking only inside our own disciplines, we need to look beyond them. Many of my colleagues in political science analyze legislatures and study committee negotiations and other activities. Some of my colleagues in economics study markets and study bidding processes and other properties within them. Both are fine, but we must find ways of crossing those boundaries when we are analyzing a legislative decision that would affect bidding processes in a fish commodity market. When we try to understand and compare the differences between how fishers organize based on laws in place, social hierarchies, and fish supply in two coastal regions such as Maine (Acheson 1993, 2003; Wilson et al. 1991; Wilson, Yan, and Wilson 2007) and the eastern shore of Canada (Finlayson and McCay 1998; McCay 1979), we cannot focus *only* on the biological or the social. We need both.

The main problem we encounter when we try to do interdisciplinary research, such as the example above, is the differences among disciplinary languages. This problem will not be solved rapidly. It is a problem that is important enough, however, that we must take the initial steps to try to solve it and then bring in others to broaden our views and continue the work. In this lecture, I discuss an SES framework that I initially developed for a special issue of the *Proceedings of the National Academy of Sciences USA* called "Going beyond Panaceas" (Ostrom 2007) and later revised in *Science* (Ostrom 2009). In the initial effort, I was fortunate to have the active involvement of the other members of the group preparing papers for that special issue, including Fikret Berkes, Buzz Brock, Stephen Carpenter, Ruth Meinzen-Dick, and Harini Nagendra, as well as my co-organizers, Marco Janssen and Marty Anderies. Thus, the first published version of the SES framework reflected several years of intense discussion across the social and biological sciences. Those of you who have been following it closely will see that what I present here involves small changes, because my colleagues and I keep working on how to improve it (see McGinnis and Ostrom 2011).

A BIT OF BACKGROUND

Before I describe the SES framework, let me go back in the history of its development to discuss briefly the Institutional Analysis and Development (IAD) framework, because working with frameworks actually started in the late 1970s. The first publication of IAD was in 1982 (Kiser

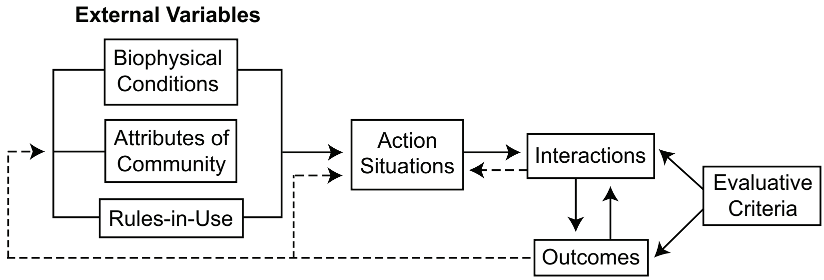

FIGURE 1. A framework for institutional analysis. *Source:* Adapted from Ostrom 2005, 15.

and Ostrom 1982), and it is embedded in what we are talking about now. I want to make sure you see the relationship.

A key component of the IAD framework is the Action Situation (see figure 1). An action situation could be this, a lecture, involving colleagues who organized it, the lecturer, and members of the audience. Another one would be my plane ride to California to give this lecture, or getting through the airport to find my way to other transportation. Well-studied action situations exist inside a market or a legislature.

The IAD framework provides a multidisciplinary language to examine how external variables impact on situations that generate interactions and outcomes. We started with biophysical conditions, community attributes, and rules in use. These external factors directly generate or affect an action situation, which generates interactions, which in turn lead to outcomes. Then, either internal or external evaluative criteria enter the picture to determine whether the outcome is perceived by the participants to be good or bad. If it is negative, the participants may try to adjust the structure of the action situation so as to generate better outcomes over time.

Over a long period of time, we have studied a wide variety of action situations, from urban police departments to irrigation systems to forest ecosystems and associated livelihoods (see Ostrom 2011; Blomquist and deLeon 2011; Bushouse 2011; and Oakerson and Parks 2011). Having ridden in police cars on and off for fifteen years when we studied urban police around the world, I can tell you a two-officer car is quite a different action situation from a one-officer car, especially if the unit is a K–9 patrol. Irrigation systems around the world offer a great variety of action situations due to size, ranging from very small to very large, and the kinds of problems people face. Forest ecosystems offer even more

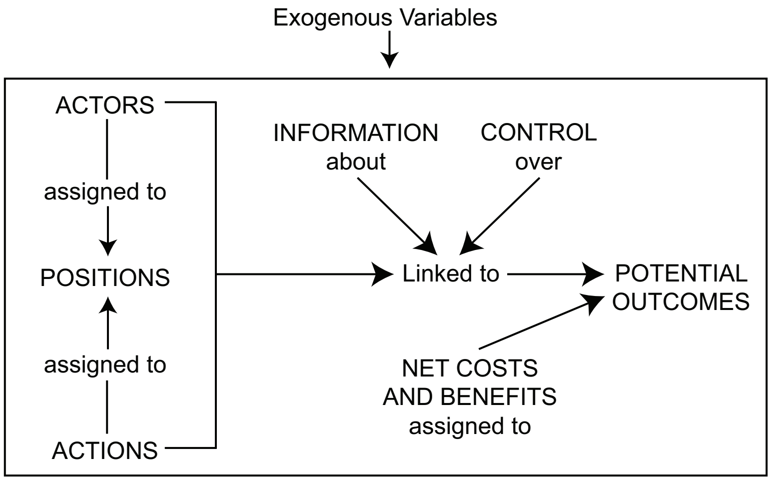

FIGURE 2. The internal structure of an Action Situation. *Source:* Adapted from Ostrom 2005, 33.

action situations; we are studying more than 250 forests around the world with different sets of rules related to them. In every case, we have used the notion of an action situation to help us frame the research we do.

In looking at our efforts to use the IAD framework to analyze resource policies, however, ecologists have often said, "You give us only one box?" They found it distressing that we were talking about water, forestry, and other ecological phenomena, and this was all boxed in to include both the physical and the biological factors that affect an action situation. Well, that began to get to me. And after discussing the internal structure of an action situation, you will see that the biophysical has much more than one box in the SES framework.

The internal structure of an action situation (figure 2) is an effort to try to understand the working parts of an action situation as these affect outcomes. We identified seven internal working parts that are present in all action situations (as well as in formal games that share internal working parts with action situations). I have never seen a repetitive situation that one might be interested in analyzing where these parts are not relevant.

Game theory and lab experiments are ways of positing working parts of an action situation predicting outcomes and then testing predictions in the lab. We have been studying the challenge of overcoming social dilemmas related to common-pool resources for some time and looking at these using formal models (Weissing and Ostrom 1991; Gardner and Ostrom 1991). We took the common-pool resource situation and examined it in the experimental lab using the early mathematical formula that Scott Gordon (1954) developed. We discovered that when people do not know one another, cannot communicate, and their actions are anonymous, they overharvest (Ostrom, Gardner, and Walker 1994). Actually, they overharvest more than game theory predicts. Thus, we have shown that under the conditions of anonymity and no communication, the prediction of overharvesting is correct.

Then you change the action situation and allow people to engage in face-to-face communication, which game theorists believe is “cheap talk” because there is no third-party enforcer and promises can be easily broken. Enabling communication is, however, very powerful. More than sixty experiments have looked at the role of communication in one way or another and found it conducive to higher levels of cooperation (see Sally 1995).

In the field, I often observed farmers reacting rapidly to observed infractions and calling general attention to them. I suggested to Roy Gardner and Jimmy Walker that we could do a formal model and an experiment where people had to pay a fee in order to sanction someone else, that is, impose a fine. We did it and participants reduced their harvesting, but they overused punishment. So the net benefit was not as good as people have interpreted. Many people have read the article we wrote to describe the results, but did not notice the difference between improved gross outcomes and worse net outcomes (Ostrom, Walker, and Gardner 1992). However, when people were allowed to design their own harvesting and monitoring rules—giving them a chance to be their own institutional designers—those who created new rules for themselves obtained close to optimal outcomes. One of the reasons I love being able to do experiments is that normally in the field, I cannot tell if the participants are at 30 percent, 50 percent, 70 percent, or 90 percent of optimal outcomes. I can tell whether farmers are doing better in field setting A than field setting B, and how much water they are getting and things like that, but I do not know the optimal distribution of benefits and costs in most field settings. That is what is so exciting about being able to formalize a common-pool resource problem and test it in the lab.

The lab experiments gave us a very rich background. We could assess whether game theory identified universal behavior in social dilemma situations. The answer is no. When we made slight changes, we saw different kinds of outcomes. In the field, we found many different settings, which is why we did experiments to try to assess the impact of some of the major

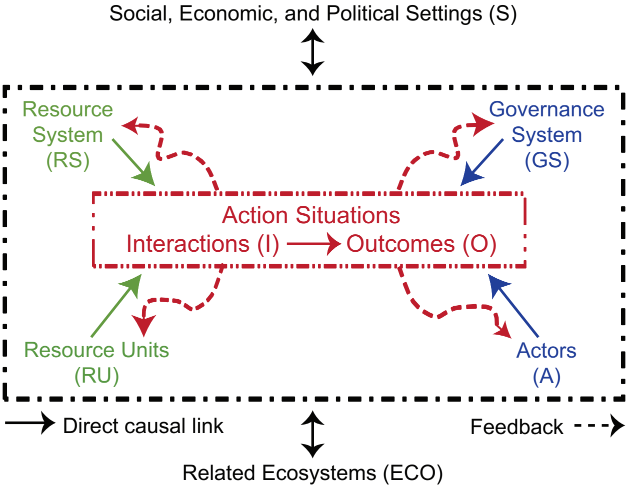

FIGURE 3. Action Situations embedded in broader social-ecological systems. *Source:* Adapted from Ostrom 2007, 15182.

variables we were observing in many field settings. One of the advantages in the lab is that we have a microsetting, so we are controlling the number of people and what they can do, and we can have a broad set of variables to observe in the same basic situation. We do not have that level of control out in the field.

DEVELOPING A BROADER FRAMEWORK

Based on our fieldwork, game theory, and lab experiments, we decided that we needed to embed the action situation in a broader setting—the SES framework. The 2007 and 2009 versions of the SES framework used Interactions and Outcomes without the term "Action Situation." I assumed, incorrectly, that users of the framework would recognize that these were the result of an action situation. But I wasn't specific enough. We now have the action situation overtly shown in the SES framework (see figure 3).

The framework gives us a way of trying to understand what is going on in the world. How can we discuss these things in meaningful ways across a variety of disciplines? We are developing an ontological language for social-ecological systems. Some people ask, "What's an SES?" It could be many things. Basically, it is where ecological and social variables create diverse action situations, interactions, and outcomes. It could be a lake in Wisconsin. Brock and Carpenter (2007) wrote a good discussion about the Wisconsin lakes using this framework. It could be the Great Lakes. It could be an ocean. Or it could be a tiny lake surrounded by a housing development.

The concept of an SES can be widely applied. Researchers have to choose what they are interested in analyzing rather than the subject of an SES always being particular systems such as irrigation, forests, or the global climate. In general, we can think about a Resource System, Governance System, Actors, and Resource Units impacting the structure of Action Situations. Now, this way of thinking is not just social or biophysical. And a focal system is embedded in Social, Economic, and Political Settings as well as Related Ecosystems (both of which could be larger or smaller than the focal system).

The SES framework can be thought of as a complex, nested system. Within each of those big, broad systems are second-tier variables. And within every second-tier variable there are third and frequently fourth and fifth tiers. Here is where Herbert Simon (1957, 1999) has been a very major influence on my thinking. Frequently, we have to realize that the problem is actually three levels down from where we are looking, and it is not apparent every time; we have to ask the questions.

We are slowly understanding and working on that second tier (table 1). We can go further down, but this is the first step in identifying variables that affect the structure of interactions and outcomes—action situations. For example, Governance Systems includes operational, collective-choice, and constitutional rules, which may affect the likelihood of people to self-organize. The asterisks indicate variables that empirical research has identified as influencing self-organization (see Ostrom 2009).

Do we know how large a resource is? How productive it is? How large is the governing organization? Is it too large for a small resource or large enough for a large resource? These are the variables people frequently talk about, sometimes as if one or the other is the *only* variable that affects the likelihood of self-organization. Many say if a group of users or managers is too big, forget it. Well, we have seen very large groups function very well. How do you manage a large resource if you are a small group? This is why I talk about the *configurations* of relevant variables. If you are 150 people with a very small inshore fishery, you have a problem. But if you are 150 people with a big forest, you may be big enough to handle it. The relationship between the resource system and the number of actors is the crucial relationship involving size. Further, rules that fit the local resource system and resource units and the culture of the actors are also

TABLE 1. Second-Tier Variables of a Social-Ecological System

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 System (RS)	**Governance System (GS)**
RS1—Sector (e.g., water, forests, pasture, fish)	GS1—Government organizations
RS2—Clarity of system boundaries	GS2—Nongovernment organizations
RS3—Size of resource system*	GS3—Network structure
RS4—Human-constructed facilities	GS4—Property-rights systems
RS5—Productivity of system*	GS5—Operational rules*
RS6—Equilibrium properties	GS6—Collective-choice rules
RS7—Predictability of system dynamics*	GS7—Constitutional rules
RS8—Storage characteristics	GS8—Monitoring and sanctioning processes
RS9—Location	
Resource Units (RU)	**Actors (A)**
RU1—Resource unit mobility*	A1—Number of users*
RU2—Growth or replacement rate	A2—Socioeconomic attributes of users
RU3—Interaction among resource units	A3—History of use
RU4—Economic value	A4—Location
RU5—Number of units	A5—Leadership/entrepreneurship*
RU6—Distinctive markings	A6—Norms (trust-reciprocity)/social capital*
RU7—Spatial and temporal distribution	A7—Knowledge of SES/ mental models*
	A8—Importance of resource (dependence)*
	A9—Technology used

essential. These variables impact the action situations that generate interactions and outcomes, which likewise lead to feedback processes.

So how does that help us? Partly, we are trying to build a language system that can be shared across disciplines. It is a conceptual language system, not just a dictionary. Across disciplines, we need a "common" language so that we can study similar systems systematically that have some of the same variables, but not others, and assess which combination of variables has a positive or negative impact on interactions and outcomes.

TABLE 1 (*cont*). Second-Tier Variables of a Social-Ecological System

Action Situations: Interactions (I)	**Outcomes (O)**
I1—Harvesting levels of diverse users	O1—Social performance measures (e.g., efficiency, equity, accountability, sustainability)
I2—Information sharing among users	O2—Ecological performance measures (e.g., overharvested, resilience, biodiversity, sustainability)
I3—Deliberation processes	O3—Externalities to other SESs
I4—Conflicts among users	
I5—Investment activities	
I6—Lobbying activities	
I7—Self-organizing activities	
I8—Networking activities	
I9—Monitoring by users	
Related Ecosystems (ECO)	
ECO1—Climate patterns.	**ECO2—Pollution patterns.**
ECO3—Flows into and out of focal SES.	

*Subset of variables found to be associated with self-organization.
Source: Adapted from Ostrom 2009, 421.

Scholars have proposed many panaceas: some believe a resource needs to be privatized because of a particular problem. Others believe government should become the owner. Some of these work in some settings but not in others. By meshing studies in various disciplines within the framework, we can begin to see which governance systems work with which kinds of resource systems. One diagnostic question is: under what conditions might a group of actors organize themselves, and when will the users themselves organize? And, after they have organized, the next question is: will their organization be sustainable?

In the supplemental online materials for my 2009 *Science* article (Ostrom 2009), I developed a self-organization model, of which I am very proud. It is a formal mathematical theory that lays out the internal calculations affecting people's actions. Basically, to achieve self-organization, expected benefits need to be greater than expected costs for most of the actors. Unfortunately, we rarely have quantitative information about the specific benefits and costs for particular users. They are inside people's heads, and we do not have a meter to measure their thoughts.

Let us say we want to figure the expected cost of leading a meeting to determine a set of rules. Some of you may love being department heads and think it is great fun deciding on a new rule to govern a department. For you, the experience is positive. For others sitting in the same room, they may not want to argue about and decide on new rules. The experience is negative for them. So developing an empirically valid model of this situation is very difficult.

AN ILLUSTRATION: THREE MEXICAN FISHING COMMUNITIES

I am going to illustrate some of the benefits of using the SES framework with a discussion of three fishery communities in Mexico. Xavier Basurto, assistant professor at Duke University Marine Lab, was a postdoc at the Workshop in Political Theory and Policy Analysis for two years. Xavier and I worked extensively on the SES framework during that time (Basurto and Ostrom 2009). Earlier, in his master's program, he started studying fisheries in the Gulf of California—Kino Bay, Puerto Peñasco, and Seri Village of Punta Chueca (figure 4). Based on his earlier studies (Basurto 2005, 2006, 2008), we were able to analyze whether these three

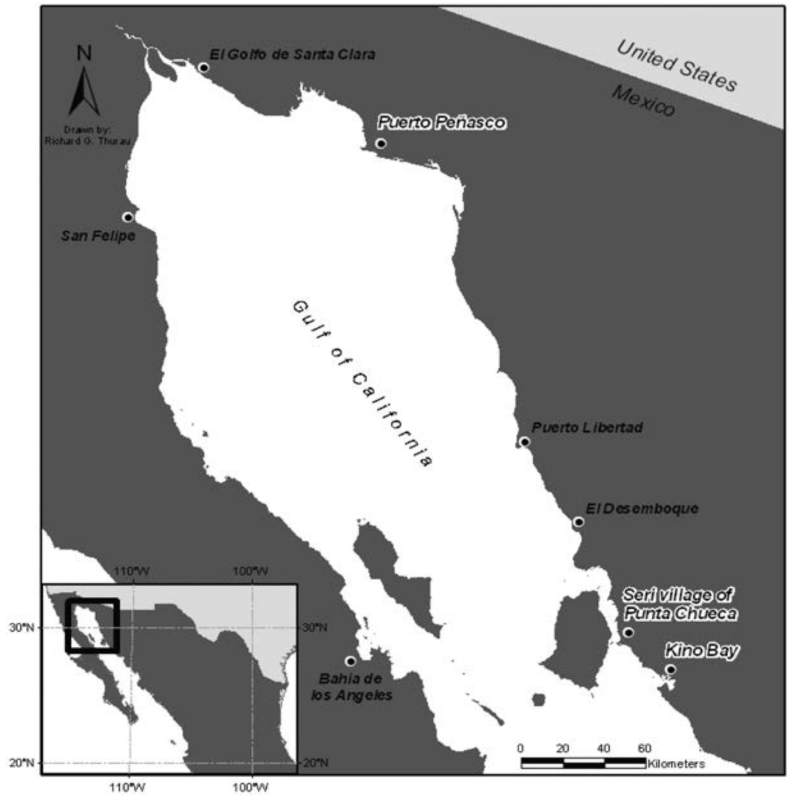

FIGURE 4. Three fishing villages (*highlighted*) Basurto studied in the Gulf of California, Mexico. *Source:* Adapted from Basurto and Ostrom 2009, 40.

communities would self-organize using the SES framework (Basurto and Ostrom 2009).

Seri Village is an indigenous community recognized by the government with its own rights and authority to manage its fish. Many villages fight very hard for recognition, and some have received it, but not all that are officially recognized by an external government actually develop their own organization on the ground. Kino Bay is large but not recognized. And Puerto Peñasco, way up to the north and far away from the government center, was able to self-organize and set up a reserve for mollusks without official government recognition.

Pen-shell sessile mollusks are very tasty and valuable, but only an experienced fisher can tell from the outside the size of the mollusk on the inside. They use small boats to take themselves out to good fishing areas and then dive to gather the mollusks. What Puerto Peñasco did was to declare an island off the coast of their community "off-limits" for several months each year. A nongovernmental organization working with the fishermen wanted to monitor the population of mollusks on the island to ascertain if the reserve was making a difference. Xavier was involved with the monitoring team that was counting mollusks over time. They found (Cudney-Bueno and Basurto 2009) that the reserve was indeed improving the mollusk population—a very exciting result.

Now, on table 2, I list the variables identified in the policy literature to be related to self-organization (see Ostrom 2009 and table 2). Looking down the Kino Bay column, we can see the pattern of variables that made it almost impossible for that community to self-organize: absence of leadership, lack of trust and reciprocity, lack of local knowledge about their resource, large resource size, and other negative variables. Seri Village had a fairly easy time self-organizing its fishery due to many positive variables in addition to its formal recognition as an indigenous community (Basurto and Coleman 2010). Puerto Peñasco had developed a very positive form of self-organization in the reserve it created. It did have local leadership, high levels of trust as well as shared knowledge, and a relatively small fishing resource. Another reason that has not been frequently identified in the literature (but should be as more studies find it to be important) was that the fishing resource was very isolated.

In this study, Kino Bay definitely differed from the other two villages. Kino Bay has not self-organized and thus has allowed open access to its resource. In figure 5, we can see the huge number of boats in Kino Bay waiting to go out to compete for fish. In contrast to Kino Bay, the fishers

TABLE 2. Comparison of Variables Posited to Affect Likelihood of Self-Organization: Three Coastal Fisheries in the Gulf of California

	Kino Bay	**Puerto Peñasco**	**Seri Village**
Actors (A)			
A1 (number of actors)	Rapid growth	Rapid growth	Slow growth
A5 (local leadership)	Absent	Present	Present
A6 (norms of trust and reciprocity)	Lacking	High levels	High levels
A7 (shared local knowledge-mental models)	Lacking	High levels	High levels
A8 (dependence on resource)	Low	High	High
A9 (technology used)	Same	Same	Same
Governance System (GS)			
GS4 (formal property rights)	Absent	Absent	Present
GS5 (operational rules)	Present	Present	Present
GS8 (monitoring and sanctioning)	Mostly absent	Mostly present	Mostly present
Resource System (RS)			
RS3 (resource size)	Large	Small	Small
RS5a (indicators of productivity)	Least available	Moderately available	Mostly available
RS7 (predictability)	Least predictable	Moderately predictable	Moderately predictable
Resource Units (RU)			
RU1 (resource unit mobility)	Low	Low	Low
Successfully self-organized	No	Yes	Yes

Source: Adapted from Basurto and Ostrom 2009, 50.

FIGURE 5. Kino Bay is an open-access regime. A very large number of boats work off Kino Bay fishing grounds. Boat counts by Basurto regularly yielded seventy-plus boats, a symptom of their inability to control access to the fishing grounds from fishers from other communities along the coast. As a result of the open-access regime, their sessile mollusk fishery has been overexploited, which is measured by fishers' inability to sustain constant harvesting of sessile mollusks year-round before they become too scarce and small in size. Photograph by Peter M. Sherman (permission granted for publication).

of Seri Village were able to self-organize their fishery and will be able to sustain their fishery over the long run. Figure 6 shows multiple boats, but only a half-dozen can be seen in this picture. I am told that the most boats ever observed at one time was in the range of ten to fifteen.

This illustrates the use of the SES framework to help understand findings from the field. While we frequently study more than three sites, these sites are located on the same coast, and Xavier spent substantial time in the region. Thus, it provides a strong example of using the SES framework to understand patterns of relationships found in the field. I will report on several studies that are based on large-*N* studies of SESs later in the lecture.

So we begin to see the difference between these communities and why two were able to self-organize while the third remains open access

FIGURE 6. Seri Village of Punta Chueca. The Seri Village residents have developed a common-property regime to govern their sessile mollusk fishery and successfully control the number of boats that have access to their fishing grounds. At any given time, you observe only ten to fifteen boats. Photograph by Xavier Basurto (permission granted for publication).

and never self-organized. Now we can ask if the two communities that self-organized are sustainable or robust. Will they last over time? This involves an analysis using the "design principles" I identified in 1990 that distinguish community organization that survived challenges over time as contrasted to those that self-organized but did not survive over time (Ostrom 1990). The Puerto Peñasco community organized a system that was characterized by most of the design principles (e.g., the boundaries were well defined, the distribution benefits were roughly proportional to costs, collective-choice and monitoring arrangements had been developed along with graduated sanctions and conflict-resolution mechanisms). Their system, however, had not received minimal recognition from the Mexican government to organize. Thus, their village was not nested in multiple layers of governance.

What then happened in Puerto Peñasco was that fishers from way down the coast heard about their reserve and the abundance of mollusks now in the fishery. While these fishers had not traveled that far north up the coast before due to the high cost of the long trip, many of the southern fisheries were severely overfished. Thus, many fishers from southern communities traveled north to fish in the reserve that the Puerto Peñasco residents had established with such hard work. Then, the Puerto Peñasco fishers said, "Oh, they are fishing us out. We need to go into the reserve ourselves and fish. After all, we did all this hard work. And why should we sit around and let everybody else take the benefit of our hard work?" Once they began to fish in the reserve along with all of the fishers from the South, the mollusk fishery collapsed.

Unfortunately for them, the Puerto Peñasco residents did not receive formal governmental recognition of their right to make rules about their own fishery. In the early years of the reserve, other fishermen had not yet heard about their reserve and did not travel up the coast to fish. Consequently, they were able to establish the reserve themselves and monitor their own community effectively. When other fishers did start to fish in their reserve, the Puerto Peñasco residents tried repeatedly to get government officials to recognize their rules as legitimate and enforceable. Unfortunately, they were unsuccessful in gaining recognition from the government of Mexico of their right to make and enforce their own rules.

FINDINGS FROM LARGE-*N* FORESTRY STUDIES

I now want to briefly discuss our forestry research because I think we have some findings that are very surprising for many scholars. The International Forestry Resources and Institutions (IFRI) is a long-term collaborative research program and network. It was established in the early 1990s, drawing on the IAD framework for many of the variables included in the data collected about forests and communities using forests. We relied on a large number of ecologists and foresters to help us develop reliable measures of forest conditions. The challenge of developing the IFRI database is one of the foundations for the creation of the SES framework. IFRI now has centers located in Bolivia, Colombia, Ethiopia, Guatemala, India, Kenya, Mexico, Nepal, Tanzania, Thailand, Uganda, and the United States (Gibson, McKean, and Ostrom 2000; Wollenberg et al. 2007) (for current information about IFRI, see http://www.sitemaker.umich.edu/ifri/home).

IFRI is unique among efforts to study forests. It is the only interdisciplinary, long-term monitoring and research program studying forests owned by governments, by private organizations, and by communities in multiple countries. Its research instruments contain most of the variables identified in the SES framework (Poteete and Ostrom 2004). Forests are a particularly important form of resource system given their key role in climate change–related emissions and carbon sequestration, the biodiversity they contain, and their contribution to rural livelihoods in developing countries. A "favorite" policy recommendation for protecting forests and biodiversity is government-owned protected areas (Terborgh 1999).

In an effort to examine whether government ownership of protected areas is a necessary condition for improving forest density, Hayes (2006) compared the rating of forest density (on a five-point scale) assigned to a forest by the forester or ecologist who had supervised the forest 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 diversity of purposes. *No* statistical difference existed between the forest density in officially designated protected areas versus all other governance arrangements for forested areas.

Chhatre and Agrawal have now 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" (2008, 13287). Recent studies by Coleman (2009) and Coleman and Steed (2009) also find that a major variable affecting forest conditions is the investment by local users in monitoring (I9 in table 1). Further, when local users are given harvesting rights, they are more likely to monitor illegal users themselves.

Detailed field studies of monitoring and enforcement as they are conducted on the ground illustrate the challenge of achieving high levels of forest regrowth without active involvement of local users (see Agrawal 2005; Andersson, Gibson, and Lehoucq 2006; and Tucker 2008). Our research shows that forests under different property regimes—government, private, communal—sometimes meet enhanced social goals such as biodiversity protection, carbon storage, or improved livelihoods. In other settings, these property regimes fail to reach such goals (Dietz, Ostrom, and Stern 2003). Indeed, when governments adopt top-down decentralization policies, leaving local officials and users in the dark, stable forests may become subject to deforestation (Banana and Gombya-Ssembajjwe 2000; Banana et al. 2007). 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, how specific rules are developed and adapted over time, and whether users consider the system to be legitimate and equitable (for an overview of the IFRI research program, see chapter 5 in Poteete, Janssen, and Ostrom 2010).

In closing, I hope I have convinced you with these empirical studies that there is some value in the SES framework as well as the use of multiple methods for studying SESs. In the second Tanner Lecture, I will focus on another resource system: water in the American West.

References

Acheson, James M. 1993. "Capturing the Commons: Legal and Illegal Strategies." In *The Political Economy of Customs and Culture: Informal Solutions to the Commons Problem,* edited by Terry L. Anderson and Randy T. Simmons, 69–83. Lanham, MD: Rowman & Littlefield.

———. 2003. *Capturing the Commons: Devising Institutions to Manage the Maine Lobster Industry.* Hanover, NH: University Press of New England.

Agrawal, Arun. 2005. *Environmentality: Technologies of Government and the Making of Environmental Subjects.* Durham, NC: Duke University Press.

Andersson, Krister, Clark Gibson, and Fabrice Lehoucq. 2006. "Municipal Politics and Forest Governance: Comparative Analysis of Decentralization in Bolivia and Guatemala." *World Development* 34, no. 3: 576–95.

Banana, Abwoli Y., and William Gombya-Ssembajjwe. 2000. "Successful Forest Management: The Importance of Security of Tenure and Rule Enforcement in Ugandan Forests." In *People and Forests: Communities, Institutions, and Governance,* edited by Clark C. Gibson, Margaret A. McKean, and Elinor Ostrom, 87–98. Cambridge, MA: MIT Press.

Banana, Abwoli Y., Nathan Vogt, Joseph Bahati, and William Gombya-Ssembajjwe. 2007. "Decentralized Governance and Ecological Health: Why Local Institutions Fail to Moderate Deforestation in Mpigi District of Uganda." *Scientific Research and Essays* 2, no. 10: 434–45.

Basurto, Xavier. 2005. "How Locally Designed Access and Use Controls Can Prevent the Tragedy of the Commons in a Mexican Small-Scale Fishing Community." *Journal of Society and Natural Resources* 18: 643–59.

———. 2006. "Commercial Diving and the Callo de Hacha Fishery in Seri Territory." *Journal of the Southwest* 48, no. 2: 189–209.

———. 2008. "Biological and Ecological Mechanisms Supporting Marine Self-Governance: The Seri Callo de Hacha Fishery in Mexico." *Ecology and Society* 13, no. 2: 20.

Basurto, Xavier, and Eric Coleman. 2010. "Institutional and Ecological Interplay for Successful Self-Governance of Community-Based Fisheries." *Ecological Economics* 69: 1094–1103.

Basurto, Xavier, and Elinor Ostrom. 2009. "Beyond the Tragedy of the Commons." *Economia delle fonti di energia e dell'ambiente* 52, no. 1: 35–60.

Berkes, Fikret. 2007. "Community-Based Conservation in a Globalized World." *Proceedings of the National Academy of Sciences* 104, no. 39: 15188–93.

Blomquist, William, and Peter deLeon. 2011. "The Design and Promise of the Institutional Analysis and Development Framework." *Policy Studies Journal* 39, no. 1: 1–6.

Brock, William A., and Stephen R. Carpenter. 2007. "Panaceas and Diversification of Environmental Policy." *Proceedings of the National Academy of Sciences* 104, no. 39: 15206–11.

Bushouse, Brenda. 2011. "Governance Structures: Using IAD to Understand Variation in Service Delivery for Club Goods with Information Asymmetry." *Policy Studies Journal* 39, no. 1: 105–20.

Chhatre, Ashwini, and Arun Agrawal. 2008. "Forest Commons and Local Enforcement." *Proceedings of the National Academy of Sciences* 105, no. 36: 13286–91.

Coleman, Eric. 2009. "Institutional Factors Affecting Ecological Outcomes in Forest Management." *Journal of Policy Analysis and Management* 28, no. 1: 122–46.

Coleman, Eric, and Brian Steed. 2009. "Monitoring and Sanctioning in the Commons: An Application to Forestry." *Ecological Economics* 68, no. 7: 2106–13.

Cudney-Bueno, Richard, and Xavier Basurto. 2009. "Lack of Cross-Scale Linkages Reduces Robustness of Community-Based Fishery Management." *Public Library of Science (PLoS ONE)* 4, no. 7: e6253.

Dietz, Tom, Elinor Ostrom, and Paul Stern. 2003. "The Struggle to Govern the Commons." *Science* 302, no. 5652: 1907–12.

Finlayson, Christopher, and Bonnie J. McCay. 1998. "Crossing the Threshold of Ecosystem Resilience: The Commercial Extinction of Northern Cod." In *Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience,* edited by Fikret Berkes and Carl Folke, 311–38. New York: Cambridge University Press.

Gardner, Roy, and Elinor Ostrom. 1991. "Rules and Games." *Public Choice* 70, no. 2: 121–49.

Gibson, Clark C., Margaret A. McKean, and Elinor Ostrom, eds. 2000. *People and Forests: Communities, Institutions, and Governance.* Cambridge, MA: MIT Press.

Gordon, H. Scott. 1954. "The Economic Theory of a Common Property Resource: The Fishery." *Journal of Political Economy* 62, no. 2: 124–42.

Hayes, Tanya. 2006. "Parks, People, and Forest Protection: An Institutional Assessment of the Effectiveness of Protected Areas." *World Development* 34, no. 12: 2064–75.

Kiser, Larry L., and Elinor Ostrom. 1982. "The Three Worlds of Action: A Metatheoretical Synthesis of Institutional Approaches." In *Strategies of Political Inquiry,* edited by Elinor Ostrom, 179–222. Beverly Hills, CA: Sage.

McCay, Bonnie J. 1979. "Fish Is Scarce: Fisheries Modernization on Fogo Island, Newfoundland." In *North Atlantic Maritime Cultures: Anthropological Essays on Changing Adaptations,* edited by Raoul Andersen, 155–88. The Hague: Mouton.

McGinnis, Michael D., and Elinor Ostrom. 2011. "SES Framework: Initial Changes and Continuing Challenges." *Ecology and Society.*

Meinzen-Dick, Ruth. 2007. "Beyond Panaceas in Water Institutions." *Proceedings of the National Academy of Sciences* 104, no. 39: 15200–205.

Nagendra, Harini. 2007. "Drivers of Reforestation in Human-Dominated Forests." *Proceedings of the National Academy of Sciences* 104, no. 39: 15218–23.

Oakerson, Ronald J., and Roger B. Parks. 2011. "The Study of Local Public Economies: Multi-organizational, Multi-level Institutional Analysis and Development." *Policy Studies Journal* 39, no. 1: 147–68.

Ostrom, Elinor. 1990. *Governing the Commons: The Evolution of Institutions for Collective Action.* New York: Cambridge University Press.

———. 2005. *Understanding Institutional Diversity.* Princeton, NJ: Princeton University Press.

———. 2007. "A Diagnostic Approach for Going beyond Panaceas." *Proceedings of the National Academy of Sciences* 104, no. 39: 15181–87.

———. 2009. "A General Framework for Analyzing Sustainability of Social Ecological Systems." *Science* 325, no. 5939: 419–22.

———. 2011. "Background on the Institutional Analysis and Development Framework." *Policy Studies Journal* 39, no. 1: 7–28.

Ostrom, Elinor, Roy Gardner, and James Walker. 1994. *Rules, Games, and Common-Pool Resources.* Ann Arbor: University of Michigan Press.

Ostrom, Elinor, Marco Janssen, and John Anderies. 2007. "Going beyond Panaceas." *Proceedings of the National Academy of Sciences* 104, no. 39: 15176–78.

Ostrom, Elinor, James Walker, and Roy Gardner. 1992. "Covenants with and without a Sword: Self-Governance Is Possible." *American Political Science Review* 86, no. 2: 404–17.

Poteete, Amy, Marco Janssen, and Elinor Ostrom. 2010. *Working Together: Collective Action, the Commons, and Multiple Methods in Practice.* Princeton, NJ: Princeton University Press.

Poteete, Amy, and Elinor Ostrom. 2004. "In Pursuit of Comparable Concepts and Data about Collective Action." *Agricultural Systems* 82, no. 3: 215–32.

Sally, David. 1995. "Conversation and Cooperation in Social Dilemmas: A Meta-analysis of Experiments from 1958 to 1992." *Rationality and Society* 7: 58–92.

Simon, Herbert A. 1957. *Models of Man.* New York: Wiley.

———. 1999. "The Potlatch between Political Science and Economics." In *Competition and Cooperation: Conversations with Nobelists about Economics and Political Science,* edited by James Alt, Margaret Levi, and Elinor Ostrom, 112–19. New York: Russell Sage Foundation.

Terborgh, John. 1999. *Requiem for Nature.* Washington, DC: Island Press.

Tucker, Catherine M. 2008. *Changing Forests: Collective Action, Common Property, and Coffee in Honduras.* New York: Springer.

Weissing, Franz, and Elinor Ostrom. 1991. "Irrigation Institutions and the Games Irrigators Play: Rule Enforcement without Guards." In *Game Equilibrium Models II: Methods, Morals, and Markets,* edited by Reinhard Selten, 188–262. Berlin: Springer-Verlag.

Wilson, James, John French, Peter Kleban, Susan R. McKay, and Ralph Townsend. 1991. "Chaotic Dynamics in a Multiple Species Fishery: A Model of Community Predation." *Ecological Modelling* 58, nos. 1–4: 303–22.

Wilson, James, Liying Yan, and Carl Wilson. 2007. "The Precursors of Governance in the Maine Lobster Fishery." *Proceedings of the National Academy of Sciences* 104, no. 39: 15212–17.

Wollenberg, Eva, Leticia Merino, Arun Agrawal, and Elinor Ostrom. 2007. "Fourteen Years of Monitoring Community-Managed Forests: Learning from IFRI's Experience." *International Forestry Review* 9, no. 2: 670–84.

LECTURE II. ANALYZING ONE-HUNDRED-YEAR-OLD IRRIGATION PUZZLES

ABSTRACT

A century ago, Katharine Coman (1911) wrote an article titled "Some Unsettled Problems of Irrigation." Coman was intrigued by the diverse efforts to solve problems of irrigation management in the American West given the entirely different ecological conditions of the area in the United States west of the hundredth meridian. She wrote extended descriptions of what was happening on many irrigation systems, but it is hard to accumulate understanding from the extended descriptive research. The Social-Ecological Systems framework initially discussed in my first Tanner Lecture provides a conceptual language for comparing complex systems and addressing which variables may make a difference. Coman focused on the "the resource system of the American plains" that underlay all of the irrigation systems she described and focused on the diverse governance systems involved. Her descriptions illustrate the general lesson that simply imposing government property or private property on an irrigation system does not guarantee results. Successful collective action depends on many factors. Among the most important is whether those involved can gain sufficient knowledge about a complex system and gain trust that others will cooperate with them to engage in collective action in this challenging environment.

Thank you again for inviting me to present these two Tanner Lectures and for your input and wonderful discussions. I have learned a lot and realize that I will have to think hard about the term "framework." Obviously, the term has confused people. The SES framework that I am discussing in these two Tanner Lectures is a nested conceptual ontology that brings together concepts from both the biological and the social sciences about relationships between humans and resource systems. I will explore alternate terms, but for now I will continue to use the term "framework."

WHY AN ONTOLOGY?

In the first Tanner Lecture, I stressed the need for an ontological approach—meaning nested concepts at multiple tiers—for understanding social-ecological systems and as a foundation for a common language and analytical approach. I am very concerned, having worked in interdisciplinary groups like the Beijer Institute in Stockholm, that scholars interested in resource-governance questions do not have a common language. Thus, sometimes we argue an incredibly long time just because we are using the same term to mean dramatically different things and we do not realize that we are using language so differently.

Now, if it were just a simple common-language problem and not a struggle to develop a common language to understand complex and changing systems, we would not need an *ontology* or *framework.* Unfortunately, if we are going to talk about a variety of resource systems, as well as public goods more generally, we cannot use a really simple language that is not itself complex and nested. In my training in economics for both my undergraduate and my graduate degrees, I was taught that simple models are the best approach for analysis. For some problems, I still buy that argument. However, I have read and studied a lot since then. I do not reject simple models just because they are simple—only when they predict incorrectly. I was a student of Armen Alchian in my undergraduate program. Alchian wrote an important article (1950) in which he argues that the simple theory of a market works well for the analysis of strictly private goods in a highly competitive environment. It is a fascinating article that argues that economists can model the individual in such a setting using the neoclassical model of the individual, because at equilibrium the survivors will have, for some reason or another, chosen strategies that maximize private returns. Thus, market theory works well, but not necessarily because everybody is a maximizer of net private returns.

As an institutional theorist, I really appreciate Alchian's approach because he stresses that the reason the economic models frequently predict well is due to their application to the institution of a competitive market matched with private goods with no externalities. When you have that match, you can use the simple model of individual choice even though it may not explain how individuals are making economic decisions. Alchian even argues at one point that market participants could even be making choices randomly. His basic argument is that market theory predicts equilibrium outcomes well for competitive markets related to private goods whether participants are maximizing individual private returns or not.

What I am most concerned about is how we can cumulate understanding across disciplines, how we can cumulate knowledge, and the importance of using multiple methods. We must realize that we can learn from multiple approaches and gain more cumulation of our scientific knowledge. Even though no one can use all of the analytical approaches or all of the methods that may seem appropriate—it takes a long time to learn some of them—we should have more empathy, understanding, and willingness to engage with others who use other approaches and methods.

I wish to focus on complex SESs that are composed of four broad variables—resource systems, governance systems, resource units, and actors—that jointly affect action situations and are embedded in social, economic, and political settings and related ecosystems (see figure 3). It is the action situation within which we have actors interacting and outcomes. We can frequently use existing microtheory to predict outcomes, and as further work is developed relating to a behavioral theory of action, we are slowly improving our capacities to predict and explain outcomes. Doing field research, we frequently cannot gain accurate information about the benefits and costs perceived by actors, so we make predictions based on the broader variables that are measurable and how we expect they will impact one another.

As I discussed in the first Tanner Lecture, we can be thinking of the SES in terms of the action situation in the middle. The actors are individuals (or organized groups) who have knowledge and are seeking outcomes in light of knowing what other people are doing, yielding interactions and outcomes. In some settings, we might have the necessary information—the size of the resource, the number of actors who have certain decisions in their action set and access to the information they need, and so forth—to predict outcomes. In many of the empirical settings we examine when interested in resource sustainability, we do not have that accurate micro-information. Our problem, then, is how we look at the broader variables that we can observe and for which we can gain rough measures, so we can begin to get a sense of how they affect action situations. And all the variables feed back and forth over time. Then all these variables are embedded in social-ecological, economic, and political systems and related ecosystems. They are complex, nested systems (table 3). Thus, I am talking about ontological systems where we might be looking at the second level, but must consider the first, third, and possibly deeper levels. In the process, I am searching for a common language, one that helps us accumulate across disciplines.

Some analysts return from observing a single success and say, "Oh, look, here is a success story. All we now need to do is copy it." We may be able to copy the institution, if we really understand all of the underlying norms

TABLE 3. Resource Systems, Resource Units, and Actors That Affect Irrigation Action Situations

Resource system	**Attributes described by Coman**
Type of resource system	Semiarid plains
Location	United States west of 100th meridian
Productivity of land for farming	Varied but generally low
Clarity of watershed boundaries	Difficult to assess without careful measurement
Constructed infrastructure	Not well developed as of 1910
Diversion dams	Extremely expensive requiring advanced engineering
Headworks	Expensive to build in many settings
Channels	Less expensive—manual labor sufficient for some projects
Road network	Patchy and expensive to construct
Resource units	**Attributes described by Coman**
Spatial distribution of rainfall	Irregular
Temporal distribution of rainfall	Irregular—from two to twenty inches per year
Economic value of land	Low
Economic value of water	High
Actors	**Attributes described by Coman**
Homesteaders	
Economic status	Relatively poor without knowledge of farming in West
Dependence on irrigation	Very dependent on availability and reliability of supply
Federal officials	
Members of Congress	Passed legislation without much knowledge of plains
Federal agency officials	Built and operated systems authorized by federal law
State officials	Involved in planning when authorized by federal law
Local officials	Frequently not involved unless local water districts created
Shared knowledge about resource system	Low at the initial stages of a project
Shared norms among actors	Relatively low unless established organizations involved
Construction technology available	Relatively primitive

Source: Ostrom 2011, 55.

and rules in use. But that doesn't mean we can copy the elevation and steepness of a mountain system or the precipitation pattern or any of the other things that have to do with the resource system. We have to try to decide what factors of that resource system affect which action situations existing in this setting.

In the first lecture, I gave an example of analysis undertaken with Xavier Basurto in three fishing villages on the west coast of Mexico (Basurto and Ostrom 2009). There we were able to show that while we were not able to obtain precise measures of second-tier variables, based on fieldwork we could assign "low, medium, and high" scores to those variables repeatedly identified as related to self-organization. We are hoping that other scholars will also use the SES framework to examine self-organizing processes to assess further the role of these ten variables (or potentially others) in explaining why some actors do self-organize and others do not.

focusing on the second tier

In this lecture, I will talk more about the second-tier set of variables introduced yesterday (see table 3). We will see these second-tier variables repeatedly today, because we will use them to analyze a set of water-resource cases in the American West. Last summer, the editors of the *American Economic Review* sent me a fascinating article written by Katharine Coman and asked me to comment on it. It was the first article in the first issue of the first volume of that journal, published in 1911. The *American Economic Review* is celebrating its one hundredth anniversary this year, and the editors asked a number of folks to comment on articles in that first issue. I had never heard of Katharine Coman, but I thought it was neat that a woman had written the first article. I soon discovered that her topic was just as intriguing, because she discussed some unsettled problems of irrigation in the American West. And her treatment of the topic was very impressive (see also Coman 1912a, 1912b).

Coman was talking about collective-action problems far ahead of Scott Gordon (1954) or Garrett Hardin (1968) or Mancur Olson (1965). She didn't deal with the theory of collective action or use the term, but she was really talking about major, complex collective-action problems. She described an incredible number of failures, but also a few successes. I found her article fascinating. It consisted, however, of a lot of individual stories, and I had a hard time gaining cumulative sight from them. At the end, I said, "Oh, interesting. What have I learned?" So I spent quite a bit of time trying to understand what we could learn and how we could cumulate the information. The traditional writing style in 1911 was very different from what it is today, as she talked about one case on page 3, then came back to it on page 5, and again on page 8. I am not criticizing her, because in 1911 that was pretty much the traditional way of writing. But do we just reject it as old-fashioned, or can we learn from it? I will argue that we can use the SES ontological framework to help us learn more from the article.

LEARNING FROM THE CASES

Coman pointed out that the American West was for many people the "curse of the continent." Massachusetts, Vermont, and the rest of the East Coast had large settlements of people and extensive rainfall. Settlers brought riparian water law from England. Landowners "owned" water that went through or next to the land they owned. That was what settlers and officials thought was the appropriate way to organize water rights. Well, when they arrived in the West, they found that some places had only two inches of rainfall instead of twenty and that it was highly irregular. The national government had a real incentive to settle the West, because a huge, open territory with no settlers could be easily lost to other land-seeking governments. So people, especially farmers, were encouraged to go West. The western environment that Coman described was difficult enough that the early settlement efforts were really big problems.

What I tried to do, and it took me some time to do so, was to look at what she was talking about in all of her disperse descriptions. It finally dawned on me that one of the first things we could do with the SES framework would be to identify a number of variables that were uniform across all of her cases. That was neat, because if we can find that some variables in a complex system are constant, we can then say, "In this environment, if A, B, and/or C are different across cases, they are the source of differences in the outcomes." Coman was not trying to do this; in fact, she didn't go beyond stating the stories because she was really puzzled about why there were failure after failure and only a few successes.

As a first step, I reread and coded the action situations—the microsettings that are repetitive in the water-governance system and other things she described. She talked a lot about the construction of irrigation systems because so many failed at this stage. Many were started but never finished; others were finished but not maintained, because there were no incentives for people to maintain them, and they disintegrated. If water runs through an irrigation system for ten or fifteen years and people don't maintain it, the system falls apart. Coman also wrote extensively about the economic survival of farmers—the homesteaders. They had been lured to the West by the government saying to poor people, "You want some land? Here is what we are going to do. You come on out West! You make a promise that you are going to settle so much land and you will receive some land, but you have use the land for a set period of time. And you have to pay for it, but the land is really cheap. Then you have to stay there and invest, or you don't get the land." Many people responded to this offer and headed West. Some were successful and many were not. My close reading and coding revealed three action situations: (1) the construction of the irrigation systems, (2) the maintenance of these systems, and (3) the economic survival of the farmers.

Applying the Framework to the Early Years of Settlement in the American West

Coman described the same kinds of resource systems that are found across many parts of the American West. The resource units are also about same, and the actors involved are about the same. She didn't intentionally set up her study to hold the three major second-tier variables constant; the similarities were inherent in her work because she was studying a large area but similar region that was basically arid but with irregular rainfall. The relevant actors involved were the people who wanted to acquire land and to have water to use for farming the land. So let's take a look at those types of variables and what she was describing.

Resource Systems

If we think about the resource system, Coman was describing the semiarid plains. The plains involved land, water, soils, and infrastructure—a cluster of specific variables in the United States, west of the one hundredth meridian. The productivity of this land was variable, but not very high.

Few land surveyovrs had been out West before the 1890s, so the boundaries of the watersheds were not well known. Making the land usable meant building dams and headworks, which required skill and money. And if people needed to pull water from its source to divert it, they had to have a dam and headworks, which were very expensive to build. The irrigation channels were easier to build, and the manual labor of the farmers was usually sufficient. But, overall, everything was difficult to accomplish. They had a patchy network of roads and trails to get there, to bring equipment for their farms, and to take produce to the market. So these variables related to the research system are relatively constant across all the cases Coman talked about.

Resource Units

Then, looking at the resource units, the first one to consider is rainfall, which was highly irregular, from two to twenty inches from year to year in no predictable spatial pattern. The economic value of the land was very low, because nobody was using it and nobody was getting anything productive out of it. Yet the economic value of the water was very high. So again, the resource units were relatively similar across all of the cases she looked at.

Actors

The actors Coman described were individually diverse. Most of them, however, were from a broad set of actors that did not vary dramatically across the diverse cases she portrayed. A key group of actors was the farmers. The US government wanted farmers to settle in the West. The homesteaders who really wanted to settle were usually poor and knew only eastern-style farming. A farm in Massachusetts is entirely different from a farm in Arizona. So the new settlers didn't have western farming knowledge, and they often went west as a family or small group rather than a community and had to cope with the strangeness and be very self-reliant.

At the same time, most state officials didn't know how to deal with the influx of people or what the homesteaders needed in their first years of residence. This was quite a different situation that they found themselves coping with. And Coman repeatedly stressed that they did not know what they were doing. At the national level, congressmen also did not know what they were doing. They passed legislation about settling in the West without ever having been there or truly knowing what problems lay ahead. They did have money. Once they realized that the land was useless without distributing water, they authorized the development of the Reclamation Service, which I will talk about later, and authorized by federal law that irrigation systems be built.

So if we look at who the actors were, we have the homesteaders, who were generally poor and very dependent on irrigation; the state officials, who were barely coping with the growing population and their needs; and the federal congressmen, who desperately wanted to populate the West to avoid losing the land to other countries and ordered the building of irrigation systems without an overall plan. Local officials were also in the mix but frequently were not involved and shared little of their knowledge, that is, there was a very low level of shared norms. And regarding the knowledge of these actors with respect to the construction of irrigation systems, this existed at a relatively primitive level in the late 1890s. So there was a lack of that kind of knowledge.

Thus, resource systems, resource units, and actors were relatively similar across the four cases that Coman discussed in some detail. While they were not precisely identical, they were similar enough that one can dig into four of the cases that she described and examine the *variance* in their governance systems while considering the broadly similar resource systems, resource units, and actors.

Action Situations

Coman discussed several action situations. In the main, she looked at decisions made inside the legislature or government bureaucracy or private firms that were building some of the irrigation systems. The diverse outcomes that were achieved, however, occurred primarily in three types of action situations. I will focus on the three that she explained in some detail and how different policies taken by relevant governance systems affected the outcomes.

Coman did not employ the term "action situation" or the word "game." Also, she did not overtly stress the tie between governance systems and outcomes that occurred in the relevant action situations, as I have derived from her descriptions. But she provided enough information that we can begin to get a pretty good understanding of those three action situations as affected by four differently structured governance systems. As I said, the action situations were constructing the irrigation systems in the first place, maintaining them in the second, and dealing with the farmers' economic problem of survival in the third.

Governance Systems

Now that we have organized much of the information that Coman provided in a somewhat scattered fashion, we can look at the governance systems. The resource systems, resource units, and actors were pretty constant across the four situations that she described in some detail. But the governance systems varied, and she gave us enough information to be able to dig into the structure of each of the four governance systems.

As Coman pointed out, many people involved in settling the West lacked the knowledge they needed. And many times the cost was too great, the projects were much more time consuming than expected, and they couldn't finish them. The rough terrain in the West made it difficult. Her article mentioned that many of the farmers had a hard time surviving, because they had to start farming immediately after arriving (see also Coman 1912a and 1912b for a further history of settlement patterns in the American West). So a farmer moves away from familiar surroundings, goes across vast expanses of land and treacherous mountains on a horse or horse-drawn wagon, arrives where there are no roads, and has a vague idea of where his land is. Then he sets about farming as he has done in the past and discovers the land is hard as rock because it has never been plowed. Many of these settlers acquired their new land through a purchase plan that required them to start paying the balance they owed in five years. They also had to show they were using water in order to keep the land, which meant they had to either tap into an existing government-built irrigation system, if they did not have water on their own land, or build one from their own water source. Coman stressed that many farmers went bankrupt.

The Desert Land Act of 1877

Coman talked about numerous governance systems, but I am going to discuss four of them, in detail, to set the structure of a governance system. The first one is the Desert Land Act of 1877 (see table 4). It was one of the very first acts of Congress that applied to the western region. At that point, Congress really did not know very much about the American West, other than they wanted to settle it. And Congress basically said, "Okay, we are going to give people a lot of land if they will pay for it at a pretty low price and water it." People were making an initial payment of 25 cents per acre, and even back then that was a pretty low price to be able to stake a claim to a large piece of land. So if they paid 25 cents per acre and got that land watered, they eventually started harvesting food to eat and sell and had something they could farm. After five years, they had to start paying another $1 per acre to purchase the rest of their land. So the total cost to the farmer was $1.25 per acre. The crux of the whole problem was that farmers had somehow to water the land, and the first legislation regarding settlement did not include much about how the farmers were going to do that. So here is where private firms enter the picture, thinking, "All these settlers need to show they have water in order to keep their land. We can set up private water companies and provide it to them!"

The private water companies promised the farmers, "We are going to get you water right away," and the farmers would start paying the fees

TABLE 4. Governance System and Outcomes of Action Situations under the Desert Land Act of 1877

Governance system	**Attributes described by Coman**
National legislation	Desert Land Act of 1877
State legislation	Not relevant
Rules regarding homestead process	
Amount of land assigned	Homesteader assigned 320 acres
Formal rights to land assigned	Paid 25 cents per acre at time of entry; had to irrigate the land within three years, then pay $1 per acre
Property rights to water	Riparian in most states
Ownership of irrigation system	Private for profit companies
Financing of irrigation system	Companies charged farmers flat rate per acre of their homestead
Monitoring of relevant transactions	No one assigned this responsibility
Conflict-resolution arenas	Regular court system
Action situations	**Outcomes reported by Coman**
Construction of irrigation systems	Private companies without adequate engineering entered and built faulty systems with exaggerated claims. Majority of projects failed.
Maintenance of irrigation systems	Few maintained.
Farmer economic survival	Most funds contributed by farmers to acquire land and pay for irrigation water were lost. Many settlers ruined.

Source: Ostrom 2011, 56.

for the expected service. However, few of the water companies survived. They simply didn't have the technology, didn't know what they were doing, and went belly-up. Well, that left the farmers in poorer financial shape and still without water; they had a problem. So this governance system was not successful. If we think about it, we can find the cause of the problem. The national legislators back East allocated land to people under various programs and said, "You can have the land if you have a certain amount of money and you use the land that is assigned to you." So they were assigned 320 acres for an initial fee of $80 (25 cents per acre) and had to irrigate within three years and complete the payment at $1 per acre. The property rights in that era were still riparian. They used the eastern property-rights system.

The irrigation systems were owned by private, for-profit companies. The irrigation companies charged the farmers a flat fee per homestead acre. So they came to the farmers and said, “Pay us this much and we will provide water for your land.” Some were successful, but many failed to produce the system or the water. No one was assigned the responsibility of monitoring the performance of these new irrigation systems. It was done by the honor system, and disagreements were settled in the regular court system. However, getting to a court hundreds of miles away without good roads took time and was expensive.

The three action situations under the Desert Land Act of 1877 are summarized in table 4. Coman said that all sorts of private companies entered the irrigation construction business without engineering backgrounds and didn’t know much about what they were doing. They went west, told the farmers “Pay us, pay us, pay us,” made exaggerated claims about what they would do, and often built faulty systems. If a part of the system was actually built, no one maintained it, or might not have known how to maintain it. Most of the projects failed, and the farmers’ economic survival was at the brink of disaster. The funds contributed by farmers to acquire land and pay for irrigation water were lost. So many of them returned bankrupt from this government effort to help them settle the western expanse of the country. It was definitely a failure.

The California Wright Act of 1887

The California state law known as the Wright Act of 1887 was an effort to establish local government irrigation systems (see table 5). The idea was that resident freeholders could vote to establish a local special district that could issue bonds, buy mortgages on the farmers’ lands inside the district, and tax the land to cover interest and maintenance of the system. I studied a California water district in the 1960s and have a continuing interest in them. I have seen a lot of successes, and I thought, “Oh, this is interesting. They were really trying to do this way back then?” I didn’t know about this part of California irrigation history, so I found it quite fascinating.

According to Coman, a number of the government districts did succeed, but many failed. Her descriptions of the Desert Land Act and the California Wright Act illustrate the failure of many government systems as well as the failure of many private systems. The irrigation districts were organized by the freeholders themselves, through financing bonds and monitoring performance. They had elected boards of trustees and voted

TABLE 5. Governance System and Outcomes of Action Situations under the California Wright Act of 1887

Governance system	**Attributes described by Coman**
National legislation	Not relevant
State legislation	California Wright Act of 1887
Rules regarding homestead process Amount of land assigned Formal rights to land assigned	Not relevant
Property rights to water	Riparian
Ownership of irrigation system	Irrigation districts organized by freeholders under state supervision
Financing of irrigation system	Bonds issued by district secured by mortgage on farmers' lands; taxes imposed to cover maintenance
Monitoring of relevant transactions	Elected board of trustees and voting by freeholders for extraordinary contracts
Conflict-resolution arenas	State courts involved in long and costly litigation
Action situations	**Outcomes reported by Coman**
Construction of irrigation systems	Many systems started but frequently underestimated costs, and initial bond did not generate sufficient funds. Many systems were not completed.
Maintenance of irrigation systems	Few systems maintained.
Farmer economic survival	Many farmers faced financial ruin exacerbated by the need to finance two bond issues in some systems.

Source: Ostrom 2011, 57.

for the contracts themselves. So there was oversight by locals. They used state courts for litigation when problems arose, and some cases dragged on for a very long time and were very costly.

If we look at the construction action situation, many systems were started, but the costs were frequently underestimated. The initial bonds that passed and provided the money were based on bad estimates, and they couldn't finish construction of the systems because costs were higher than estimated. Thus, many systems were not completed. Teele provides a clear overview of the extent of failure when he summarizes a report of the

US Department of Agriculture (Hutchins 1921) that provides statistics for all of the special districts that had been organized by the early 1920s: "Of the 248 districts organized up to December 31, 1921, for the purpose of reclaiming new lands, only 46, or 18.5%, were operating at that time" (1926, 436).

And obviously, few systems were maintained because the completion rate was so low. Many farmers faced financial ruin exacerbated by the need to finance two bond issues. Not only did they have to emigrate to the West, but they had to cough up the money for the first bond issues. So the failure rate for farmers was, again, very high.

The Carey Act of 1894

Coman went on to discuss the Carey Act of 1894. Senator Carey of Wyoming, evidently a person who had been a farmer himself with quite a bit of experience, was very distressed by the earlier failures and tried to design legislation that would do better. He had the interesting idea of having state administrative officers oversee the homesteading process. So instead of maintaining federal ownership of the West, Congress gave large portions to individual western states and told them to oversee their local settlements. Senator Carey wanted surveys done in advance, so that some of the problems of ignorance by state officials and farmers of the conditions of the land involved would be solved by the results of the survey. Under the Carey Act of 1894, the US government handed more than one million acres of public land to states in the West that wanted to take on the responsibility of oversight.

States could then sell the land to settlers who signed a contract with a water company, agreeing to buy water rights after the irrigation system was constructed. Private companies were to construct the systems, and in this setting they had strong incentives to make them operational, as they did not receive money from the settlers until after the irrigation systems were completed. Once a system was operational, the companies could sell the water rights to the farmers and move on to build another irrigation system and make a profit. So there were many profit-oriented incentives in this legislation. And the water users organized into a water users' association. They were obligated to maintain the completed irrigation system but had stock and voting rights in proportion to the amount of land they owned. As Coman stated, "The legislation . . . finally put the private irrigation of public lands on a rational basis" (1911, 10). She pointed out that

Idaho and several other states were quite successful, but there were also many failures due to, for example, the land not being sold rapidly enough to recoup the construction cost of the irrigation system or the soil not being good enough to cultivate.

So if we look at and try to analyze the situation under the Carey Act, we have national legislation but a different homesteading process in each state. Thus, each state could establish its own rules for how settlement would happen, rather than having a uniform process established for the entire West that did not well match many locations. Under the Carey Act, farmers had to homestead 20 to 160 acres of land rather than the much larger acreage required under the Desert Land Act. In order to obtain title for the land, they had to contract with a water company for water rights linked to the land, reside on the property for some time, cultivate one-eighth of the tract, and provide proof that they had completed all of these requirements. There were strong requirements in the Carey Act, but it was more feasible for all participants to meet them.

To recap, under this governance system, the irrigation system is initially owned by a private company. Then a water users' association buys the completed system from the company over a ten-year period. Farmers own stock in the company and voting rights in proportion to the amount of land they own. See the summary of the governance system and outcomes for the Carey Act in table 6.

Looking at the action situations, state engineers monitored the construction of systems and their use rather than officials at the top governing level, that is, senators and congressmen or national agency officials. State courts handled conflicts involving irrigation systems. Many systems were constructed under this plan, especially in Idaho, the model state for success under the Carey Act.

The water users' associations maintained the systems, so most of them remained functional due to the users' vested interest in keeping the water flowing. The financial security of farmers who participated in the Carey plan was much higher than under previous plans, and farmers could sell their holdings. Yes, there were financial difficulties, but it was primarily when the land quality wasn't good and the system failed. The act did really well in facilitating the settlement of the West. There were failures, of course, but most were due to unproductive land and climate conditions that made it difficult for farmers to earn the money to pay for water rights.

TABLE 6. Governance System and Outcomes of Action Situations under the Carey Act of 1894

Governance system	Attributes described by Coman
National legislation	Carey Act of 1894
State legislation	Acts adopted by Idaho, then by Montana, Utah, Colorado, Arizona, California, and New Mexico
Rules regarding homestead process	Established by state lands commission
Amount of land assigned	20 to 160 acres
Formal rights to land assigned	Contracted with water company, resided for at least thirty days, cultivated one-eighth of tract
Property rights to water	Landowners had to purchase water rights that were linked to land
Ownership of irrigation system	Initially private company. Water users' association bought completed system. Farmers owned stock and voting rights proportional to amount of land owned.
Financing of irrigation system	Landowners, through cooperative company in proportion to land owned
Monitoring of relevant transactions	State engineer monitored processes and appraised value of irrigation system
Conflict-resolution arenas	State courts
Action situations	**Outcomes reported by Coman**
Construction of irrigation systems	Many systems constructed in Idaho, but some system failures in other states where project land was particularly unproductive.
Maintenance of irrigation systems	Water users' association maintained most completed systems.
Farmer economic survival	Rate of financial security was high. Farmers could sell holding. Financial difficulties primarily when land quality was inferior.

Source: Ostrom 2011, 58.

The Reclamation Act of 1902

The Reclamation Act was a very key piece of legislation passed by the US Congress in 1902. It created the US Reclamation Service to make western lands usable and was funded with a very substantial budget of federal money. The majority of the money earned from the sale of land associated with each project was invested back into that project. About thirty projects were started immediately, which caused funding problems later as the government struggled to fund them all at the same time. In some cases, it took up to seven years to finish one project, even though the budget for each project was immense.

The delays in funding to the various irrigation projects frequently led to delays in construction. The farmers buying the reclaimed land had to do so under the Homestead Act and were required to live on the land for five years before they gained ownership. If those five years coincided with delays in construction of the associated irrigation system, the farmer could not get water to live on the land. Obviously, the whole system had some basic problems (see table 7).

National rather than state legislation governed the program. The Homestead Act applied to settlement as administered by the Reclamation Service, so again, Congress was back to requiring farmers to commit to residency for a very long time before they ever settled on their homestead. They had to live on their land for five years before receiving the title and formal ownership rights. The farmers also had to prove that half of the land was cultivated. These were very rigorous requirements, especially when their land was associated with a delayed irrigation system. Farmers could get between 10 and 160 acres, but the amount was determined by an engineer based on how much was needed to support the farmer's family. Ownership of the irrigation systems, at this point, was by the US government, and construction was slow because continued support of the projects depended on allocations from the federal budget. The US Reclamation Service, created by the Reclamation Act, monitored land and water transactions, so conflicts had to be resolved in federal court.

In regard to construction, the irrigation systems did have good engineering, and Coman stressed that the government hired some of the very best engineers in the country, because the projects were well funded. And the engineers found it very attractive to all of sudden have these big projects where they could demonstrate their knowledge. But the systems were

TABLE 7. Governance System and Outcomes of Action Situations under the US Reclamation Act of 1902

Governance system	**Attributes described by Coman**
National legislation	US Reclamation Act of 1902
State legislation	Not relevant
Rules regarding homestead process	Homestead Law applied as administered by Reclamation Service
Amount of land assigned	Between 10 and 160 acres as determined by engineers to support a family
Formal rights to land assigned	Ten annual payments, five years' residency, and proof of half of land farmed
Property rights to water	Acquired after ten payments received
Ownership of irrigation system	US government
Financing of irrigation system	US government for construction, farmers for maintenance and distribution
Monitoring of relevant transactions	US Reclamation Service
Conflict-resolution arenas	Federal court system
Action situations	**Outcomes reported by Coman**
Construction of irrigation systems	Systems had good engineering designs but were constructed very slowly by US government dependent on congressional allocation of funds
Maintenance of irrigation systems	Maintenance and water distribution of completed projects paid for by farmers and undertaken by government engineers
Farmer economic survival	Requirement that farmers must live on property five years before gaining ownership led to high rates of farmer relinquishments and loss of funds needed to survive, to start farming, and to invest in farm infrastructure

Source: Ostrom 2011, 59.

constructed slowly, because congressional allocation of funds had to be spread over thirty-one projects.

The maintenance of completed irrigation projects was paid for by the farmers. But many projects weren't finished, and the farmers' economic survival was pretty grim. The requirement that the farmers must live on the property for five years before gaining ownership was a method to make sure the homesteaders were out there in the West, but it was pretty hard on the farmers if there was no irrigation system. The rate of farmer relinquishment and loss of funds needed to survive, start farming, and invest in improvements was high.

The Minidoka Project

As we have been discussing, Coman provided us with a very interesting story of the settlement of the West. In the midst of her article, she described the Minidoka Project, which she visited, to illustrate a combination of federal and private input to complete an irrigation project in Idaho. A large amount of money had been allocated for the project, but not enough in Minidoka to build the main part of the system, buy all of the equipment, and build the lateral canals.

The farmers were irate and coming to the project office in large groups. They were demanding that the irrigation system be completed. In response, one of the project engineers came up with an ingenious idea. The engineer suggested that they take all the money the federal government was providing and use it to buy all the expensive equipment—power and pumping machinery—needed for the project. There was enough money for this purpose but not enough to buy the equipment *and* finance the labor to build the lateral canals. He suggested that the farmers should build the lateral canals. He had such faith in the idea and was so enthusiastic that he was able to persuade six hundred farmers to join the effort. He promised that the project office would buy the equipment, and they believed him. They worked together to build the laterals to get water from the headworks to the fields.

The engineer also made an intriguing suggestion that the government "pay" the farmers for their labor in "water scrips," which the farmers could then use to pay the government for their share of the maintenance cost of the irrigation systems, purchase land, or use at local banks and stores to meet immediate needs. It was a very creative idea and was working well, until the US attorney general said issuing the water scrips was illegal because it constituted creation of money, which was the purview of the US Treasury. This shock disheartened the progress on the project but was eventually overturned by a recommendation of President Taft, and the water-scrip system continued for the Minidoka group and then was adopted by about fifteen other projects.

Thus, the Minidoka Project was a very interesting form of collective action where the government agency used money for one purpose—buying expensive equipment that the farmers did not have the expertise to build or operate—and the farmers contributed their own effort and expertise to build a core part of the irrigation system itself.

LESSONS

What are the theoretical and practical lessons we can learn from Coman's article about successes and failures in western irrigation efforts? Basically, she concluded that settling the West by investing in irrigation was very difficult and referred to situations that were "unsettled problems." Her cases, for me, illustrate one weakness that is still a part of today's policy process. Each of the plans professed they had found a panacea to accomplish the task of settling the West: government is always the way, or private enterprise is always the way, or local communities are always the way. She illustrated all of them, and illustrated that they do not always work.

Most government-sponsored private systems weren't successful. Then, surprise, the most successful program, designed by a US senator experienced in irrigation problems, comes along to incorporate government, private companies, and local community organization. Senator Carey designed a governance system that was, outside of some failures, very successful.

The important lesson I glean from Coman's article is that assuming actors have complete information about alternative and potential outcomes in these kinds of policy settings is rarely appropriate. On page 18 she stated, "The wisest and most experienced of the project engineers are agreed that the chief difficulty of the farmer on the government projects is lack of capital." The adopted policies dealt with only one type of capital—land—to cope with their "lack of capital." But to develop effective capital in the American West required much more than a single material asset whose value depended upon so many other factors related to the resource system, resource units, governance system, and the other actors involved.

Under the restrictions of the Reclamation Act, homesteaders could not secure titles to their land until they had been in residence for five years. Coman was critical of the act in that its requirements created an economic hardship for any farmer trying to help the government settle the vast western territory. On her last page, she quoted project engineer Thomas Means, saying, "If a settler could obtain some form of title to his place more promptly and so have something on which he could borrow money, he would often make good where he now fails." It appears that the main concern Coman pulled from her research is the economic condition of the settlers.

In her very last paragraph, she concluded, "Congress has made the long-term residence requirement absolute just where it is least needed. If the commutation permissible under the Homestead Act were allowed, and a man might pay down the statutory price of the land, the position of the homesteader would approximate that of the settler under the Carey Act." So she did find the Carey Act a little more successful than the others.

However, even more effective would have been the suggestion that the residency requirement be dropped or abated. Of course, that would not avoid the profit makers who would cheat the purchase arrangement by leaving their lands to sit without improvement until an irrigation system, built by others at no expense to themselves, was in place, then sell their lands for much higher prices. However, if the residency requirement had been changed, the person "with small capital but possessing those more valuable qualities of brains, pluck, and endurance, would [have been] enabled to earn a farm by the labor of his hands, as truly as did his forbears in the humid states east of the Missouri River" (1911, 19).

BACK TO ACTION SITUATIONS

We have focused in this analysis of Coman's historical insights on three action situations: the construction of irrigation systems, the maintenance of these systems' economic survival, and the economic returns (or lack of returns) to farmers. We have explained much of the variation by examining the relative governance systems. The best example she gave, the Minidoka Project, incorporated all three action situations. The farmers in Idaho trusted the engineer when he promised to get all the equipment and did their part by digging the canals. Then the government maintained the system by receiving users' payments in cash or water scrips. Together they solved problems that had not been solved in many other cases. They achieved a high level of trust in each other and were then willing to cooperate at a high level of investment. I stress the word "trust" because it is needed for success in any cooperative arrangement (see Ostrom 2010).

As we look at the action situations embedded in broader SES systems, we will need to rely on a behavioral theory of human action as a better foundation for theoretical explanation and for policy analysis. It has been a critical foundation of a lot of recent work on collective action, and I think it is an absolutely essential aspect of where we are going.

In terms of future work on the SES frameworks, there are a number of colleagues working on developing and trying to improve the framework from universities and research centers all over the world, particularly in Europe. Several colleagues and I will start a new National Science Foundation project in the fall in which we will be looking at snow-fed, semiarid regions in the American West and in Kenya, where irrigation systems depend on the snowcap at the top of mountains. A key topic of research within the project will be how our climate change affects water availability and how diversely organized irrigation systems and the farmers dependent on irrigation are dealing with the change. We now have some younger scholars working with diverse ontological programs and a variety of other ontological tools for developing the framework still further. There is a lot more to be done, but we will keep moving ahead.

ACKNOWLEDGMENTS

It was a great experience giving the Tanner Lectures in February 2011 at Stanford University. In these lectures, I have drawn on research on institutions and natural resources conducted over multiple decades. In addition to new work, I have drawn on several earlier papers, and I appreciate the support for the research on which this lecture is based that has been provided by the National Science Foundation and a subcontract with Dr. Thomas Sterner, University of Gothenburg, Sweden, that is funded by FORMAS through the Human Cooperation to Manage Natural Resources (COMMONS) program. Many colleagues at the Workshop in Political Theory and Policy Analysis at Indiana University have contributed to this research through the years as well as colleagues in Africa, Asia, and Latin America with whom I have had the privilege to work. Francis Fukuyama, Margaret Levi, Charles Sabel, and Buzz Thompson were outstanding commentators on my lectures, and I learned a lot from their comments. Paul A. David sent me extensive written comments on the second Tanner Lecture that helped me deepen the historical analysis. Andrea Kuduk effectively made all of the local arrangements. Joanna Broderick did a fantastic job of in-depth editing of both of these lectures, and Patty Lezotte and David Price also effectively helped as well. I appreciate that Xavier Basurto was willing to read the first lecture and offer some useful suggestions.

References

Alchian, Armen A. 1950. "Uncertainty, Evolution, and Economic Theory." *Journal of Political Economy* 58, no. 3: 211–21.

Basurto, Xavier, and Elinor Ostrom. 2009. "Beyond the Tragedy of the Commons." *Economia delle fonti di energia e dell'ambiente* 52, no. 1: 35–60.

Coman, Katharine. 1911. "Some Unsettled Problems of Irrigation." *American Economic Review* 1, no. 1: 1–19. Reprinted in *American Economic Review* 101, no. 1 (2011): 36–48.

———. 1912a. *Economic Beginnings of the Far West: How We Won the Land beyond the Mississippi.* Vol. 1, *Explorers and Colonizers.* New York: Macmillan.

———. 1912b. *Economic Beginnings of the Far West: How We Won the Land beyond the Mississippi.* Vol. 2, *American Settlers.* New York: Macmillan.

Gordon, H. Scott. 1954. "The Economic Theory of a Common Property Resource: The Fishery." *Journal of Political Economy* 62, no. 2: 124–42.

Hardin, Garrett. 1968. "The Tragedy of the Commons." *Science* 162: 1243–48.

Hutchins, Wells A. 1921. *Irrigation District Operation and Finance.* Bulletin no. 1177. Washington, DC: United States Department of Agriculture.

Olson, Mancur. 1965. *The Logic of Collective Action: Public Goods and the Theory of Groups.* Cambridge, MA: Harvard University Press.

Ostrom, Elinor. 2007. "A Diagnostic Approach for Going beyond Panaceas." *Proceedings of the National Academy of Sciences* 104, no. 39: 15181–87.

———. 2009. "A General Framework for Analyzing Sustainability of Social Ecological Systems." *Science* 325, no. 5939: 419–22.

———. 2010. "Beyond Markets and States: Polycentric Governance of Complex Economic Systems." *American Economic Review* 100, no. 3: 641–72.

———. 2011. "Reflections on 'Some Unsettled Problems of Irrigation.'" *American Economic Review* 101, no. 1: 49–63.

Teele, R. P. 1926. "The Financing of Non-governmental Irrigation Enterprises." *Journal of Land and Public Utility Economics* 2, no. 4: 427–40.