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Strengthening The Institution-Behaviour Link In the SES Framework To Faciliate Analysis Of Environmental Public Goods Dilemmas

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Many environmental challenges take the form of environmental public goods dilemmas, including climate change, water quality deterioration and biodiversity loss. There is a great need for analysis of these challenges to better inform the design of governance institutions for adaptive and sustainable resource management. The social-ecological systems (SES) framework provides a foundational structure for analyzing the sustainability of complex and multi-scale environmental challenges. However, in its applications, the SES framework has struggled to facilitate analysis of environmental challenges beyond common-pool resource (CPR) regimes and the emergence of community-based governance institutions. In this paper, I propose that one way to facilitate application of the SES framework to environmental public goods dilemmas is to incorporate a greater focus on the link between institutions and behavior. First, I examine the attributes of environmental public goods dilemmas that differentiate them from CPR regimes. Specifically, these are the absence of behavioral feedback, multi-actor and multi-resource system dynamics, higher levels of uncertainty and complexity, and lack of built-in social capital. I suggest that these same attributes also increase the need to study a broader suite of potential governance institutions. Finally, I propose incorporating psychological and behavioral theory into the SES Framework to facilitate an increased focus on the institution-behavior link. Ultimately, a better understanding of which institutions promote behavior change within and across environmental public goods regimes can improve the sustainability of these systems.

Keywords: social-ecological systems; public goods,; environmental governance; institutions; decision making

Introduction

Many of the regional and global environmental challenges we face are environmental public goods dilemmas, including climate change, ocean acidification, declining water quality, and biodiversity loss (Rockström et al., 2009; Shortle & Uetake, 2015). Because of the scale and persistence of many environmental public good dilemmas, there is a critical need to improve our understanding of how institutions can support sustainable resource regimes in environmental public goods dilemmas. To improve our understanding of these systems we need analysis of environmental public good dilemmas to identify generalizable trends for robust and adaptive management regimes (Ostrom, 2005). The social-ecological systems (SES) framework provides a foundational structure for this type of analysis, specifically for analyzing and improving the sustainability of complex environmental dilemmas (Ostrom, 2007, 2009). The framework acknowledges the context-specific nature of human decisions and behavior within environmental dilemmas, and the existence of influences and feedbacks between the ecological and the social (Ostrom, 2011). However, the SES framework has yet to fill this analytical need for environmental public goods dilemmas. I propose that a critical gap in applications of the framework lies in relying

on behavioral assumptions about actor decision-making, in particular the lack of attention paid to how institutions shape decision-making and behavior.

In an effort to inspire transdisciplinary analysis of environmental public goods dilemmas using the SES framework, I propose to improve the link between governance institutions and actor behavior within the framework. Thus far, applications of the SES framework have been limited to the study of common pool resource (CPR) regimes and the conditions that lead to the emergence of community-based natural resource management (Thiel, Adamseged, & Baake, 2015). In this paper, I will suggest that the attributes of environmental public goods dilemmas, in particular those that differentiate them from CPR dilemmas, increase the relevance of actor behavior and decision-making for social-ecological outcomes compared to the role of actor behavior in CPR regimes. I identify these attributes as the absence of behavioral feedback, multi-actor and multi-resource system dynamics, higher levels of uncertainty and complexity, and lack of built-in social capital.

An expanded focus on the link between governance institutions and behavior within the SES framework will allow analysts to examine how institutions shape social-ecological outcomes in environmental public goods dilemmas, in light of their unique attributes. Methodologically, the expanded SES framework that I am proposing for environmental public goods dilemmas includes (1) designing research questions around the institution-behavior link, (2) incorporating new variables into the SES framework on drivers, influences and psychological components of actor decision-making, and (3) utilizing actor mental models to identify the salient components of the social-ecological dilemma. The expanded SES framework allows the analyst to draw from the literature of social psychology, cognitive psychology and behavioral economics to investigate behavior under different institutions rather than rely on behavioral assumptions. This approach allows for the examination of diverse types of institutional arrangements in a broader range of environmental resource dilemmas, including environmental public goods.

In section one, I begin by reviewing the vision behind the SES framework and outline its current constraints. In the second section, I explore the specific challenges in the management of environmental public goods for implementation of the SES framework. In section three, I build on the exploration of environmental public goods to suggest the need for examining diverse institutional arrangements with the SES framework to motivate collective action. In section four, I establish the importance of the institutional-behavioral link to address these challenges. Finally, in section five, I propose revisions to the SES framework to strengthen researchers' ability to examine the institutional-behavioral link in public goods dilemmas using the framework.

SES Framework Vision & Constraints

The seemingly simple question of which institutions promote sustainability under which social-ecological contexts is hugely complex. Variation in scale, scope, resource attributes, community attributes, market forces, and governance regimes, among other factors, makes drawing concrete conclusions and proposing solutions challenging. Furthermore, researchers analyzing these systems from different disciplinary perspectives use different terminology, use different scales of analysis and focus on different variables, which make drawing system-wide transdisciplinary conclusions difficult (Agrawal, 2003). The SES framework was proposed as a solution to this problem, following the success of a research program on CPR regimes (Poteete, Janssen, & Ostrom, 2010). The framework provides a theoretical basis from which to examine interactions between ecological resource dynamics, underlying biophysical systems, governance regimes and human behavior (see Figure 1 below) (Ostrom, 2009, 2011). These first-order variables, and the second- and third- order variables nested below them, are organized to guide research

design and data collection so that analysts can communicate across cases and begin to form theories about how SES work (for more detailed introduction to the SES framework see Ostrom (2007, 2009)). The long-term goal of the SES Framework is to enable research that can recognize "which combination of variables tends to lead to relatively sustainable and productive use of particular resources systems operating at specific spatial and temporal scales and which combination tends to lead to resource collapses and high costs for humanity" (Ostrom, 2007, p. 15183).

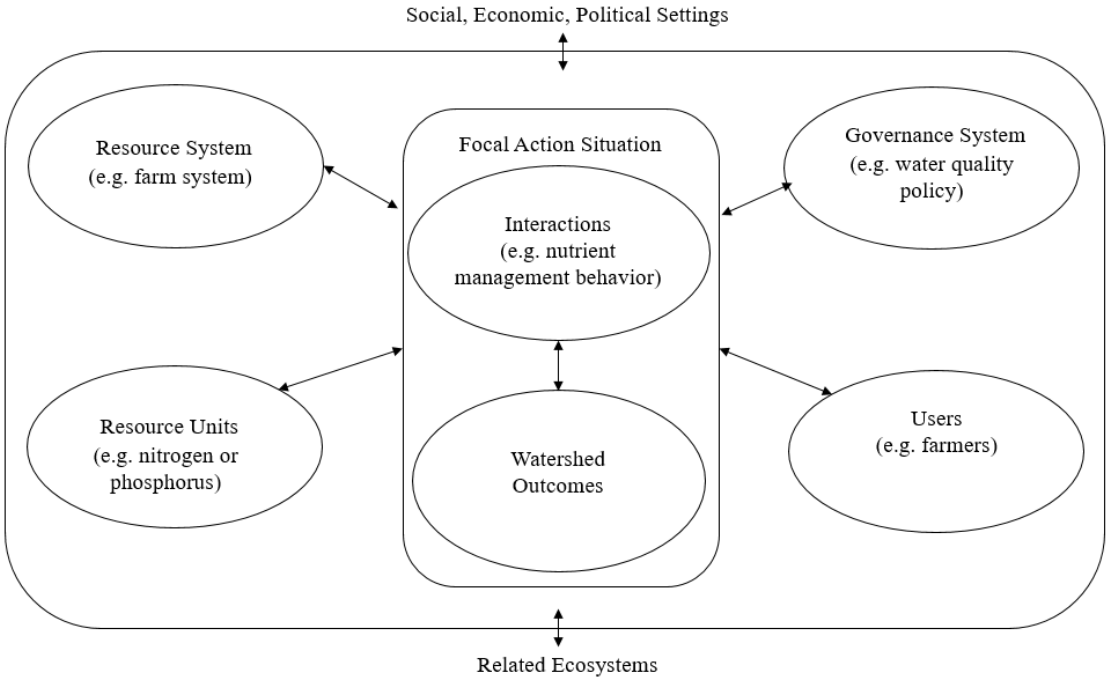

Figure 1. The SES framework with example elements of watershed agricultural nonpoint source pollution dilemma adapted from McGinnis and Ostrom (2014)

Thus far, the SES framework has struggled to live up to this initial vision. Applications of the SES framework still lie mostly within the realm of CPR regimes (Thiel et al., 2015), despite the intention for the framework to branch out to different types of resource regimes (McGinnis & Ostrom, 2014). Additionally, the framework has been applied primarily in community-based natural resource management contexts, such as when and under what conditions will resource users self-organize to address resource degradation or overharvesting (Thiel et al., 2015). Yet, the framework has the potential to examine a much wider breadth of governance questions.

Theoretically the SES Framework centers around individual behavior and the choices made by individuals or collaborative groups (McGinnis & Ostrom, 2014). The SES framework "does not dictate a particular model of decision-making; instead it prompts the analyst to explicitly identify what participants value; what resources, information, and beliefs they have, what their information-processing capabilities are, and what internal mechanisms they use to decide on strategies" (Ostrom, Cox, & Schlager, 2014, p. 274). However, in its applications, very few studies explicitly identify actor perceptions that drive behavior and how actors perceive costs and benefits (Thiel et al., 2015). This may be in part because, as Ostrom (2009) observes, "accurate and reliable measures of users' perceived benefits and costs are difficult and costly to obtain, making it hard to test theories based on users' expected net benefits" (Ostrom, 2009, p. 420). Therefore, in applications of the SES Framework, analysts tend to overlook individual perceptions and values that drive decision-making, despite the fact that these lie theoretically at the core of the framework. This relates to a broader

challenge for the SES Framework: the lack of a common understanding of what it means to apply the SES Framework (Ban & Cox, 2017).

In the following section, drawing from the vision and constraints laid out here, I explore the attributes of environmental public goods dilemmas that present challenges for applications of the SES framework.

Environmental Public Goods Dilemmas

In the disciplines of economics and political science, public goods are often defined as non-subtractable (e.g. one person's use of the good does not subtract from another person's) and non-excludable (e.g. it is difficult or impossible to exclude others from accessing the resource) (Ostrom, 2005). Another related way to consider environmental public goods dilemmas is that they are, at their core, environmental externalities. Environmental externalities occur when a behavior in a specific domain results in an output outside or external to the domain in question. This external output results in the deterioration or degradation of an environmental good shared by all. One example of an environmental public good dilemma, which I will draw on for illustrative purposes throughout this paper, is water quality deterioration from agricultural nonpoint source (NPS) pollution, as illustrated in Figure 1. In this dilemma, farmers spread nutrient fertilizers on their fields to increase agricultural yield, but as a result, these added nutrients may runoff into nearby waterbodies and decrease water quality of rivers and lakes. Environmental public goods, such as water quality, differ from the traditionally studied CPR regimes, such as irrigation networks, fisheries and forests, on a couple of important characteristics: They lack a clear behavioral feedback and they typically feature larger geographic scales, greater complexity and more uncertainty.

Public Goods Dilemmas Lack of Behavioral Feedback

CPR dilemmas also feature externalities at their core, but with an important distinction. Within CPR dilemmas, overuse of resource results in degradation of that same resource for all. Therefore, an individual who overharvests, say overfishes in a vulnerable fishery, will ultimately see reductions in their own ability to fish because of aggregate overfishing. As shown in Figure 2 below, this can be conceptualized as a negative behavioral reinforcement mechanism. Hardin described this situation in his classic Tragedy of the Commons paper: "each pursuing his own best interest" will bring "ruin to all" (Hardin, 1968, p. 1244).

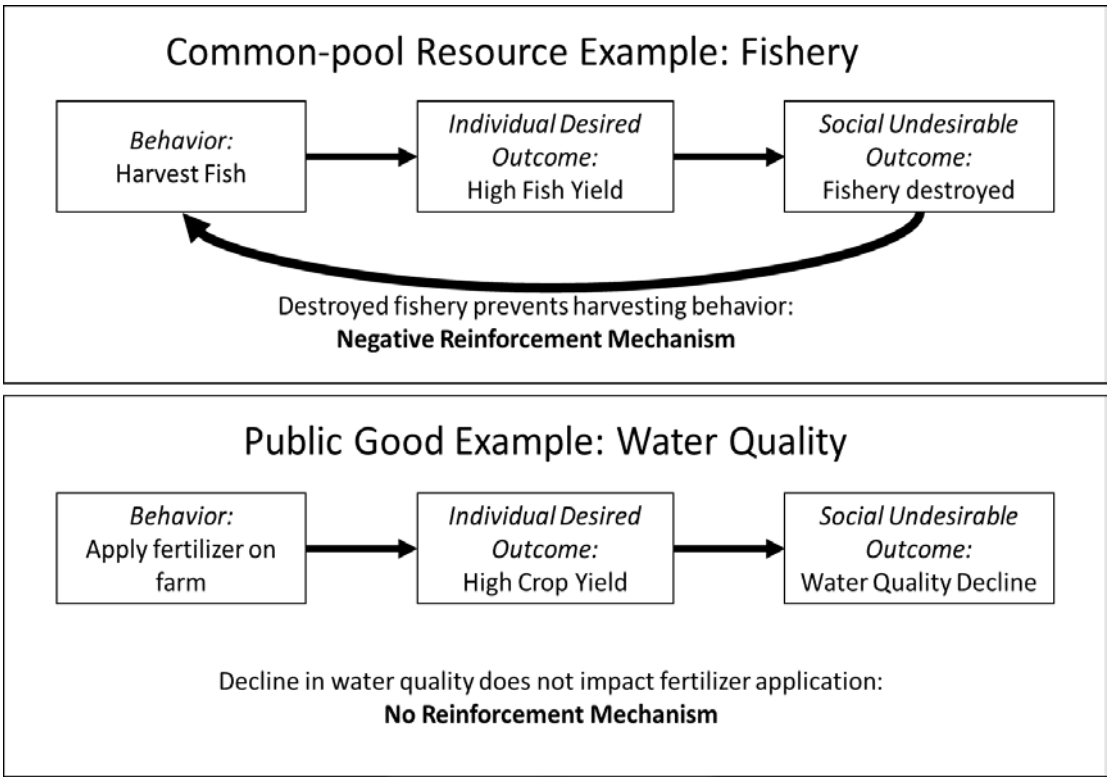

Figure 2. Resource system and resource use relationships in common-pool resource and environmental public good. Note the lack of behavioral feedback between undesirable outcomes in public good example.

This feedback link, in which the behavior in question ultimately affects the ability to engage in that same behavior in the future, is not present with environmental public goods dilemmas, as show in Figure 2. Rather, environmental public goods dilemmas often feature many different types of actors using or exploiting the same resources for different purposes (Young, 2002). In the water quality example, farmers use nutrients to produce agricultural products, and citizens more broadly enjoy water quality for recreation, aesthetics or drinking water, as shown below in Table 1. Importantly, the decline in water quality, in and of itself, will not limit a farmer's ability to apply fertilizer on the farm. This is true even if a farmer is a part of the population that also enjoys water quality.

Table 1. Characterization of appropriation and provisioning action situations for agricultural watersheds. Structure adapted from Hinkel et al. (2015).

Actors	Benefits	Activity	Stock of Resource Units (RU)	Subtractability	Resource System (RS)	Action situation (s)
Farmers	Sale of crops/ products	Extracting nutrients from soil and adding nutrients through fertilizer/feed	Nitrogen and Phosphorus	No	Farm system	Addition of nutrients at the farm scale creates a water quality provisioning problem at the watershed scale
Rural and Urban Citizens	Water quality	Aesthetics, Recreation, drinking water, local economic	Nutrient assimilative capacity of the waterbody	Yes	Watershed (biogeochemical processes)	

This lack of behavioral feedback in environmental public goods dilemmas creates challenges for characterizing the resource system within the SES Framework because it is unclear which resource system dynamics drive behavior and at which scales. Environmental public goods dilemmas generally do not feature the one-to-one resource system-resource unit link that is characteristic of most CPR regimes (e.g., Resource unit: Fish; Resource system: Fishery). Hinkel et al.'s (2015) diagnostic approach for identifying the resource units, resource system, and provisioning and/or appropriation problem using the SES Framework is not as clear cut for a public goods dilemma without this one-to-one link. Environmental public goods dilemmas typically feature at least two nested resource systems, and often many more.

Table 1 shows the relevant action situation for the example case of declining water quality in agricultural watersheds. Connected to this action situation are two distinct levels of resource system, resource units, activities, benefits and actors. The first resource system is that of the focal behavior: the farm in which a farmer is applying fertilizer to produce agricultural products. The second resource system is the higher-level system that absorbs the negative externality of the behavior in the first system: the watershed, which receives nutrients from the land into local waterbodies. Similarly, the resource units are related, but have distinct characteristics. The units of nitrogen and phosphorus at the farm system scale are units of flow on and off the farm, whereas the nutrient capacity of the waterbody at the watershed scale is a stock that can be used up or exceeded. Additional units of nitrogen and phosphorus added to farms will overwhelm the nutrient capacity of the waterbody but will not prevent farmers from adding additional nutrients to their farms in the future.

Importantly, what I am characterizing here as an environmental public goods dilemma could also be described as a number of other types of environmental dilemmas depending on perspective and context. As Young (2002) suggests, "environmental problems are socially constructed in the sense that there are almost always a number of plausible ways to think about them, and the choice

of conceptualizations is likely to have significant consequences for the interests of one or more members of the relevant group" (p. 142). For example, the issue of declining water quality in agricultural watersheds also bears elements of a CPR regime: the nutrient capacity of the waterbody can be viewed as a CPR that farmers and other landowners use (and overuse) for disposing of wastes (e.g., excess nutrients applied to fields or sewage). The key point here is that there can be multiple "correct" ways of viewing the system and that the study of these systems need to take into account these various perspectives.

Complexity and Uncertainty in Public Goods Dilemmas

Environmental public goods dilemmas tend to exist at larger geographic scales and feature greater levels of complexity and uncertainty than small-scale CPR regimes. All SES share elements of complex systems, including feedbacks, nonlinear dynamics and emergent system properties (Meadows & Wright, 2008). However, environmental public goods dilemmas tend to include multiple interacting resource systems and multiple user groups. Accounting for multiple resources systems and user groups increases the complexity of interactions throughout the system. This increased complexity can further complicate the search for sustainable resource management regimes for environmental public goods dilemmas and confound our ability to understand system dynamics and measure system outcomes.

To illustrate the complexity and uncertainty in environmental public goods dilemmas, I return to the example case of water quality deterioration in agricultural watersheds. The movement of NPS nutrient pollution throughout a watershed is dependent on both deterministic factors, such as land use and soil composition, and random, factors such as weather-related processes. Phosphorus and nitrogen molecules, whether originating from agricultural, urban storm water, or streambank erosion, are extremely difficult to differentiate from each other at the watershed scale (Moss, 2008). Therefore, it is both challenging and costly to attribute nutrient pollution to any one source (Horan & Ribaudo, 1999). The measurement of pollution is generally done at the watershed scale as farm scale models and measurements have high degrees of uncertainty (Moss, 2008). Yet, even at the watershed scale, modeling of diffuse nutrient pollution involves combining hydrological, geological, meteorological, land cover classification and other data sources across a complex, heterogeneous landscape, with trade-offs in specificity and uncertainty.

Typically, at the watershed scale, government agencies and researchers use a variety of modeling techniques to estimate and attribute NPS pollution contributions to individual sectors, such as agriculture. Management strategies within or across polluting sectors then rely on proxy measurements such as ambient water quality, or production-related measures, such as input-use or practice implementation (Horan & Ribaudo, 1999). Furthermore, at the watershed scale, the transport of nutrients from farms to waterbodies may face significant time lags in the system, again resulting in a high degree of uncertainty and unpredictability (Meals, Dressing, & Davenport, 2010). These attributes of the agricultural NPS pollution, while unique to this specific problem, are representative of the broader challenges of uncertainty and complexity that make many environmental public good dilemmas more difficult to address than small-scale CPR regimes.

The challenges outlined here, namely the multi-resource, multi-actor, highly complex and uncertain nature of environmental public good dilemmas, make them difficult to characterize within the SES Framework. In particular, it is difficult to identify which elements of the system are important to examine for motivating collective action, and how to portray these systems given multiple potential ways to conceive of them. Here I suggest, and will further describe in the fourth section below, that it is important to focus on the actors within the system, and particularly, to draw on their perceptions of the system to define the relevant elements driving behavior and collective

action. Before describing this proposal, I first need to consider another important and related gap within the applications of the SES framework: the need to apply the SES Framework to examine a broader range of institutional interventions for SES.

Examining Diverse Institutions to Motivate Collective Action

SES issues are collective action problems. In collective action problems individuals' pursuit of their own welfare leads to collective suffering. In other words, all individuals would be better off if they worked together. The collective action problem in agricultural nonpoint source pollution can be defined as: each farmer's individual pursuit of a maximum yield, realized through excessive nutrient inputs, results in poor water quality that is shared by all farmers (and other residents of the watershed). Overcoming collective action problems requires motivating individuals to pursue their collective welfare (Olson, 1971; Ostrom, 1990). In the literature on community-based natural resource management, collective action, or the need to collectively change actor behavior, is often used synonymously with user- or self-organized community management. This body of work, led by Ostrom and others, aimed to suggest that community-based, self-organized governance systems are a viable, potentially sustainable form of natural resource management. More broadly, community-based natural resource management, or self-organized management of resource systems, is just one type of institutional arrangement that can motivate collective action. Collective action can be motivated in a number of different ways, including market-based strategies, state-based strategies, or any combination of these options with community-based strategies. According to Ostrom, institutional arrangements should be context specific, hence the formation of the SES framework to guide analysis of which institutions promote sustainable system outcomes under specific conditions (Ostrom, Janssen, & Anderies, 2007).

The focus thus far on the emergence of community-based management using the SES framework is just a narrow slice of the potential institutional arrangements that could effectively manage resource systems. More broadly, there is a need to examine a diversity of potential institutional arrangements in environmental dilemmas. This is especially the case within the study of environmental public goods dilemmas, where community-based management strategies may not be the most effective or the most efficient means to address the issue. Indeed, the traditional economics perspective dictates that the state should intervene to provision public goods because individuals face incentives to freeride off the contributions of others (Singh et al., 2013). Characterizing environmental public goods as dual- or multi-resource system dilemmas, as I do above, illustrates an additional reason for this need: when compared to small-scale CPR regimes, the structure of environmental public good dilemmas does not lend itself to the emergence of social capital.

Small-scale CPR regimes typically consist of many opportunities for fostering social capital, which are not present in environmental public goods dilemmas. Social capital is the concept that norms and bonds between people and communities are important for the functioning of society and can strongly shape interactions (Pretty, 2003, p. 1913). In small-scale CPR regimes, actors typically engage with each other on a daily basis, inherently observing other actors' behavior. Furthermore, actors utilizing a resource are typically the very same individuals that are providing the public infrastructure for the resource (e.g. the head of an irrigation network is often an irrigator themselves) (Anderies, Janssen, & Ostrom, 2004). In environmental public goods dilemmas, by contrast, these conditions that lead naturally to the building of social capital, such as norms and trust, are not necessarily present. In public goods dilemmas, resource users are not often the same as the public infrastructure providers. Resource users may not be observing each other's behavior on a daily basis. Finally, it may be impossible to see the impact of each other's behavior on the

broader resource system. Therefore, reciprocity, trust, norm creation, and repeated interactions may not be feasible mechanisms to create sustainable resource management regimes.

Take, once again, the example of water quality declines in agricultural watersheds: a farmer's fertilizer use and nutrient management behavior takes place on her farm in isolation. It is difficult for other farmers to observe her nutrient management actions. Additionally, public infrastructure providers, such as employees of government water resources agencies, are typically not farmers and do not interact with farmers on a regular basis. It may be difficult for farmers to make the connection between regular nutrient applications on their farm and broader water quality issues at the watershed-scale because of the complexity challenges outlined in the previous section. Furthermore, water quality issues may be less salient to those farmers who farm higher up in a watershed when they don't experience or witness water quality issues firsthand. Therefore, the rule and norm creation, trust, reciprocity, and shared understanding may not exist amongst the farming community, making self-organized collective action on water quality very difficult. This suggests that there may be a place for other types of institutional interventions, such as regulatory or market-based policies, to encourage or require collective farmer behavior change to improve water quality. I propose that to investigate diverse institutional arrangements using the SES framework, it is important to more closely examine this institution-behavior link. This focus on how and why institutions shape behavior and decision-making is what is needed to improve our understanding and adaptive management of environmental public goods.

Expanding the Institution-Behavior Link

An increased focus on actor decision-making within the SES Framework can facilitate its application to both environmental public good dilemmas and a broader diversity of institutional arrangements. As described in the previous two sections, environmental public goods dilemmas differ from CPR regimes, the archetypal application of the SES Framework, by a number of factors, including the lack of a behavior-reinforcing feedback, multiple resource systems and actor groups, complex and uncertain biophysical dynamics, and a lack of key interactions that build social capital. These elements of environmental public goods dilemmas increase the importance of understanding actor decision-making and behavior. In this section, I will first describe how an increased focus on decision-making can improve the applicability of the SES Framework to environmental public goods dilemmas and diverse institutional arrangements. Then I will describe a sampling of social-psychological and behavioral theories of decision-making to demonstrate how pulling from theory and models in these fields can improve our understanding of SES system outcomes through incorporation into the SES Framework. In the last section of this paper, I outline how to incorporate these theories and models into the SES Framework.

The Critical Role of Actor Decision-Making in SES

The SES Framework is designed around actor interaction and behavior, but as Thiel at al. (2015) finds in their review of applications of the SES framework, actor decision-making processes, or at least actors perceptions of costs and benefits, themselves are typically not empirically analyzed. Actor decision-making and behavior are important components of any SES because ultimately, actor behavior is a key driver of both social and ecological outcomes, and moreover, one of the major leverage points that humans have to intervene in SES. I propose that the attributes of environmental

public goods dilemmas, as compared to CPR dilemmas, make actor decision-making and behavior even more relevant for SES system outcomes.

As described above, public goods dilemmas lack the behavioral feedback present in CPR dilemmas as illustrated in Figure 2. This link in CPR dilemmas serves as leverage to change self-interested actors' behaviors. It is possible to design incentives around this self-interest to motivate a behavior shift towards long-term individual (and social) payoffs. This, of course, is not a simple shift, and much research has been dedicated to designing incentives to solve this difficult problem (Ostrom, 1990; Ostrom et al., 2002; Poteete et al., 2010). However, the shift to sustainable resource management for public goods dilemmas, which lack this behavioral feedback, can be even more difficult. Without this self-interested mechanism to motivate behavior change, there must be another value-based motivator. A few possibilities include altruism, stewardship, and deterrence from fees or penalties. Drawing again from the example of water quality and agriculture, when water quality declines, there is nothing physically preventing farmers from applying nutrients to their farms. It is possible that informing a farmer of the impact of nutrient applications on the lake could inspire behavior change due to a farmer identifying with stewardship values. Whether or not this is the case would have implications for designing effective policy. Identifying and understanding what motivates collective behavior in context-specific environmental public goods dilemmas is important for the design of institutional interventions to change behavior.

The difficulty in defining behavioral motivation and incentives is further exacerbated by the multi-resource, multi-actor nature of many environmental public goods dilemmas. With different actors, using a resource, or multiple-related resources systems for different purposes, it is hard to decipher what the breadth of motivators are for distinct actor groups/resource uses. Moreover, individual actors understanding of the SES is likely to vary actor to actor. The way in which an actor perceives the SES and their role in it is likely to influence their decision-making process and behavior. Ostrom highlighted the importance of actors' mental models and knowledge of the SES on system outcomes by designating these as variables in the framework (McGinnis & Ostrom, 2014). These variables are likely to be of increased importance in studying environmental public goods dilemmas. Here again, understanding the drivers, perspectives and values that comprise actors' mental models and knowledge of the SES that underlie the decision-making process can help with identifying behavioral interventions.

In environmental public goods dilemmas, SES are often larger scale, more complex, and more uncertain. This poses a challenge for designing sustainable governance solutions because often it is impossible to accurately measure ecological system outcomes. With water quality decline in agricultural watersheds, due to time lags in the movement of nutrients from farms to waterbodies, it may take decades for collective behavior change to result in water quality improvement (Meals et al., 2010). In these cases, we often use models to project future ecological outcomes based on land use behavior. Therefore, behavior change itself becomes the proxy for ecological outcomes. The central focus on behavior change in these systems suggests that understanding the drivers of behavior to then change behavior is the most direct pathway to improve ecological outcomes.

Finally, in environmental public goods dilemmas the lack of built-in processes for building social capital amongst actors calls for greater attention to how specific institutional interventions influence decision-making. The lack of built-in processes for building social capital suggest that there is less likelihood for the emergence of community-based collective action (Pretty, 2003). This is not to say that trust, reciprocity, norms, and shared rules do not play a role in shaping behavior, but it does suggest that greater emphasis is required to understand where and how they play a role.

In making the case for the relevance of decision-making and behavior in the analysis of environmental public goods dilemmas, it is important to note that the SES framework is compatible with a wide range of decision-making and behavioral theories (McGinnis & Ostrom, 2014). This flexibility means that we can use a variety of decision-making and behavioral theories to better

understand SES actor behavior and outcomes. However, so far, this flexibility has been underutilized.

Ostrom and her colleagues were aware of the importance of incorporating a broader understanding of human behavior into the study of SES. Poteete et al. (2010), in their book on methods for studying collective action, identify this as one of the key next steps for the field. To do this, building on Poteete et al. (2010), requires drawing on a broad range of psychological and behavioral theories to empirically examine the conditions and contexts that drive decision-making and behavior with SES.

Next, I will highlight a few psychological and behavioral concepts that may be particularly relevant for the study of environmental public goods dilemmas. This is not meant to be an exhaustive list, but rather a sampling to suggest the utility of this approach. For additional reviews of decision-making theories of relevance to understanding environmental dilemmas, I refer the reader to Singh et al. (2013) and Schlüter et al. (2017).

Promising Decision-making Concepts and Theories for Environmental Public Goods Dilemmas

A number of decision-making and behavioral models exist that could prove useful for incorporation within the SES framework for the study of environmental public goods and beyond. The body of research on collective action and common pool resource dilemmas, including SES Framework applications, has typically relied upon the behavioral assumptions of bounded rationality to explain individual behavior, as suggested in Section 2 above and as stated by Ostrom (2005). This approach models decision-making as dependent upon limited information, cognitive processing, and attention in shifting individual cost-benefit analysis of potential actions (Poteete et al., 2010). Bounded rationality offers insight into the heuristics and biases that shape individual behavior, such as a greater aversion to losses than gains, anchoring on a given value rather than intrinsic values, or habit-formation (Gsottbauer & van den Bergh, 2011). Within the SES Framework, these aspects of decision-making may have important implications for institutional design, such as whether to design incentives to motivate behavior or sanctions, or what level to set a baseline incentive offer.

Social psychology also offers a number of decision-making models and theories, which are not mutually exclusive with bounded rationality. Theories such as the Theory of Planned Behavior (Fishbein & Ajzen, 2011), the Value-belief-norm theory (Stern, Dietz, Abel, Guagnano, & Kalof, 1999), and the Norm-Activation theory (Schwartz, 1977) model individual behavior as embedded in individual's beliefs and perceptions of the world. As a complement to bounded rationality, individuals' beliefs and perceptions are grounded in an individual's worldview and experience, as opposed to full information about any given decision-making situation. These social psychological theories suggest that constructs such as an individual's attitudes toward a behavior, subjective and personal norms surrounding the behavior, and perceived behavioral control, or self-efficacy in engaging in a behavior are important predictors of how an individual will behave (Bandura, 2000; Fishbein & Ajzen, 2011; Stern et al., 1999). Klöckner's (2013) comprehensive action determination model combines elements of the Theory of Planned Behavior, Norm-Activation theory and bounded rationality in an integrated decision-making model and has shown strong predictive power across a number of domains of environmental behavior.

In environmental public goods dilemmas, where individuals are faced with high levels of uncertainty and ambiguity, social psychological decision-making theories can help identify the way in which individuals are making decisions in these highly variable conditions (e.g. based on other's actions, their own level of understanding, what they think is right, etc.). Furthermore, these theories can help to identify types or typologies of actors that value different types of information and

assistance. This stands in stark contrast to an institutional rational choice model which assumes individuals to be self-interested and motivated by utility maximization (in practice mainly profit maximization).

As a proof of concept, I will suggest a few psychological and decision-making concepts from the Theory of Planned Behavior (Fishbein & Ajzen, 2011) and Value-belief-norm theory (Stern et al., 1999) that may be particularly helpful in examining actor behavior in environmental public goods dilemmas and describe their potential contribution. These are: self-efficacy and perceived behavioral control, experience and personal norms, and attitudes.

Self-Efficacy and Perceived Behavioral Control

When considering actor behaviors in collective action dilemmas, an individual's autonomy, their capacity to make their own decisions, is an important concept. Autonomy is closely aligned with the concept of self-efficacy, for motivating behavior change. According to Bandura, (1986, 2000) an individual's incentive to act is dependent upon their perceptions that their behavior will have the desired impact. Another closely related psychological concept is perceived behavioral control, which is an element of the psychological Theory of Planned Behavior (Ajzen, 1985). Perceived behavioral control refers to "a general sense of personal competence or perceived ability to influence events" (Fishbein & Ajzen, 2011, p. 153). Beliefs of self-efficacy strongly inform an individual's confidence in their ability to perform a behavior and it is predicted that those with higher levels of perceived behavioral control with respect to a specific behavior or action would be more likely to adopt the behavior (Ajzen, 1991). There is a strong link between individual self-efficacy, individual action and collective action. Individual's hold beliefs about collective efficacy within themselves, as opposed to some external representative. Therefore examining individual's beliefs about perceived behavioral control may be an important component of actor decision-making and behavior in SES (Bandura, 2000). Furthermore, different institutional arrangements intended to motivate collective behavior change in SES may impact actor self-efficacy and perceived behavioral control in different ways. This could have important consequences for overall SES system outcomes.

Experience and Personal Norms

Exposure or experience with a policy can be through participation in town hall meetings, planning committees, or public hearings, as well as measurement, monitoring or enforcement exercises can shape individual decision-making. Edward-Jones (2006) highlighted this as an important area for future research, in the light that engaging in a behavior due to policy requirements could continue to feedback on the policy goals after the end of policy. This is further in line with Krosnick et al.'s (2006) Attitude, Certainty and Existence model which includes personal experience and informant's messages as predictors of general public support for a policy agenda. Throughout a policy process and through engaging in target behaviors, individuals may be exposed to information that updates belief sets and norms to reinforce the target behavior. It is possible that exposure to a policy process activates personal pro-environmental norms. Personal norms are a component of the Norm-Activation theory (Schwartz, 1977) and Value-Belief-Norm theory (Stern, 2000) which suggest that given awareness of a behaviors consequences and personal ascription of responsibility for a given outcome, personal norms for a behavior will be activated and increase the likelihood that an individual will engage in the behavior.

Attitudes

Attitudes are a central concept to many psychological models of decision-making, including the Theory of Planned Behavior (Ajzen, 1991). According to Fishbein and Ajzen, (2011) attitudes are the "latent disposition or tendency to respond with some degree of favorableness or unfavorableness to a psychological object" (p. 76). Attitudes can be seen as an evaluation, on a scale from negative to positive, of a given action or behavior. In the context of actor behavior in environmental public goods dilemmas, actors may hold attitudes toward specific behaviors of interest that may influence whether or not they engage in the behavior. According to the Theory of Planned Behavior, one would expect an individual with positive attitudes towards an action to be more likely to engage in that action (Fishbein & Ajzen, 2011).

I propose that incorporating the study of actors' attitudes, experience and personal norms, and self-efficacy and perceived behavioral control, along with other psychological theories, into the study of environmental public goods dilemmas using the SES can improve our ability to design institutions to promote sustainability in these systems.

Incorporating the Institutional-Behavior Link into the SES

What would it look like to expand the institutional-behavior link in the SES Framework to apply it to environmental public goods dilemmas and to examine diverse institutional arrangements? Given the flexibility of the SES framework towards decision-making and behavioral theories, the incorporation can take many different forms. Here I recommend two potential approaches to strengthen the institution-behavior link in the SES framework. The first approach is to add social-psychological variables to the suite of actor attribute variables to test and explore the role of relevant psychological and behavioral theories in driving outcomes in SES. The second is to examine actor mental models within environmental public goods dilemmas to redefine SES framework categories to capture the relevant actor motivations and drivers of behavior. These recommendations complement each other and ultimately, a mixed methods approach combining both recommendations would be the most beneficial to improving our ability to identify elements of institutional design that lead to robust environmental public good regimes.

The first recommendation, to add social-psychological variables to the SES Framework, methodologically begins with framing research questions around the connection between institutions and actor behavior. For example, in the context of declining water quality due to agricultural activities, a potential set of institution-behavior questions could be: Are farmers more likely to adopt water quality best management practices in mandatory or voluntary policy regimes? Do farmer feelings of self-efficacy explain the difference in behavioral response to these policies? These questions would then drive the application of the SES Framework to a series of cases to be compared. In Table 2, I demonstrate the application of the SES Framework to these example questions by listing the variables that could be used in defining and testing the relationship of interest. First, one would define the independent variables of interest, the bold, underlined variables in Table 2. The first independent variable is the institutional variable: GS6 Rules-in-use, which is defined in this example as being either mandatory or voluntary. Then the second independent variable, "A10 Actor(s) values and motivations," is a new second tier variable that I am proposing to add to the framework under the first tier Actor category. This new variable is where theories from psychology and behavioral economics, such as those reviewed above, can be incorporated into the framework as shown in Table 2 below. Drawing from the sampling of theories reviewed in the previous section, some potential third tier variables under "A10 Actor(s) values and motivations"

are personal norms, attitudes and self-efficacy. In the example case, self-efficacy can be included as an actor attribute, falling on a spectrum from high to low.

Table 2. Example application of a revised SES framework to the case of declining water quality due to agriculture.

Social, economic and political settings (S): S1 Economic development, S2 Demographic trends, S3 Political stability, S4 Government resource policies, S5 Market incentives, S6 Media organization

Resource systems (RS)	Governance systems(GS)
RS1 Sector: watershed	GS1 Policy area
RS2 Clarity of system boundaries	*GS2 Geographic scale of governance system: state/region*
RS3 Size of resource system: large	GS3 Population
RS4 Human-constructed facilities	GS4 Regime type
RS5 Productivity of system	*GS5 Rule-making organizations: state/regional*
RS6 Equilibrium properties: declining water quality	**GS6 Rules-in-use: voluntary or mandatory**
RS7 Predictability of system dynamics	*GS7 Property-rights systems: private*
RS8 Storage characteristics	GS8 Repertoire of norms and strategies
RS9 Location	GS9 Network structure
	GS10 Historical continuity
Resource units (RU)	Actors (A)
RU1 Resource unit mobility	**A1 Number of relevant actors: few to many farmers**
RU2 Growth or replacement rate: continued nutrient applications	**A2 Socioeconomic attributes: small to large farms**
RU3 Interaction among resource units	A3 History or past experiences
RU4 Economic value	A4 Location
RU5 Number of units	A5 Leadership/entrepreneurship
RU6 Distinctive markings	**A6 Norms (trust-reciprocity)/social capital: existence of farmer**
RU7 Spatial and temporal distribution: history of nutrient	A7 Knowledge of SES/mental models
	A8 Importance of resource (dependence)
	A9 Technologies available
	A10* Actor(s) values and motivations: high or low self-efficacy

Interactions (I) -> Outcomes (O)

I1* Resource use levels of diverse users: adoption of practices	O1 Social performance measures
I2 Information sharing among users	O2 Ecological performance measures
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* Public good provisioning levels: ambient water quality	

Related ecosystems (ECO): ECO1 Climate patterns; ECO3 Flows into and out of focal SES; ECO2 Pollution patterns

Notes: New additions to the framework, or revised categories are marked with an asterisk (*). The bold, underlined variables are the example independent variables. Variables bold, italicized are example dependent variables. Variables that are only bolded are covariates and variables are only italicized are held constant. All other variables would be excluded from the example analysis. SES framework adapted from McGinnis & Ostrom (2014)

The relationship of interest is the interaction of these two variables, and their effect on the dependent variable "I1* Resource use levels of diverse users," defined here as adoption of water quality best management practices. In order to better accommodate environmental public goods dilemmas, I also propose including this revised label category for I1 ("Resource use") as opposed to the previous label for the category "Harvesting levels of diverse users", since not all resource use behavior within an SES is harvesting behavior. Furthermore, I suggest explicitly adding a variable to examine public good provisioning behavior: "I9* Public good provisioning levels." This variable could be another dependent variable of interest in the example case, defined as ambient water quality levels.

With the independent and dependent variables of interest defined, the framework can then be used to guide case selection, by selecting cases that have similar resource systems, resource units, governance systems and actors. This is demonstrated by the resource system, resource unit and governance system variables in italicized text in Table 2. These variables would define the criteria that all cases must meet to be included in the analysis. Alternatively, or within the same analysis, some variables could be allowed to vary to examine covariates of the institution-behavior link of interest. An example for these is given by the bolded variables, including farm size for socioeconomic attributes (A2) and existence of a farmer group for social capital (A6). This approach, as defined here, lends itself to a quantitative analysis in which the relationship between the dependent variable (e.g. behavior or system outcomes) and the independent variables (e.g. policy type and covariates) is measured using a regression model, system dynamic model, network model or agent-based model (Schlüter et al., 2017). The hope is that analyzing environmental public goods dilemmas with this revised version of the SES framework will ultimately inform adaptive governance. For example, the analysis can identify which institutions are adaptive for specific SES problems and their behavioral responses with the goal of producing the desired social and ecological outcomes.

The key element to incorporating this new social-psychological second tier variable (A10) is data collection, as well as agreement by the research community on standardized constructs and validated questions. Data will need to be collected from actors within the system of interest, either from surveys, interviews, experimental games or any other number of methods (see Poteete, Janssen and Ostrom (2010) for a review of methods for studying collective action problems). In doing so, it is important that a core set of psychological constructs are include and questions are asked in the same way to provide internally valid comparisons. One potential example that can be informative for this is the New Ecological Paradigm, a standardized, broadly used, internally valid questionnaire to measure environmental concern (Dunlap & Van Liere, 1978; Dunlap, Van Liere, Mertig, & Jones, 2000; Stern, Dietz, & Guagnano, 1995). This quantitative approach is one way that we can begin to better understand trends in how institutional design shapes decision-making, behavior and ecological outcomes in environmental public goods dilemmas. Furthermore, experimentation with institutional designs can also inform adaptive governance of environmental public goods dilemmas. As further governance experimentation takes place, we can use this quantitative approach to study the institution-behavior link in these systems to continue to inform sustainable governance.

The second recommendation for strengthening the institution-behavior link within the SES framework is to draw upon actor mental models to define the relevant system attributes in environmental public goods dilemmas. Mental models of actors are acknowledged to play an important role in SES outcomes and are included in the framework (see variable A7 in Figure 2)

and in many applications of the framework (Thiel et al., 2015). Mental models are individuals' internal representations of the world and are made up of concepts linked together, and it is these relationships between concepts that are used to make meaning of the world (Carley & Palmquist, 1992, p. 602). In environmental public goods dilemmas it is important to look to actors to define the concepts/variables that they perceive to be important influences on their behavior. Again, actor behavior is important because ultimately it is actor behavior that policy-makers and society in general are looking to change to improve social-ecological outcomes.

Examining actor mental models lends itself to a qualitative methodologies, much like the in-depth case studies Ostrom and others pursued in the early work on CPR regimes (Ostrom, 1990). Interviews, focus group, and other ethnographic approaches can be used to elicit actors' perceived motivations, interactions and system outcomes within an environmental public goods dilemma. The analyst can then using qualitative coding techniques such as grounded theory (Strauss & Corbin, 1994) or other forms of content analysis (see Saldaña, 2015) to identify the salient or relevant aspects of the system according to actors. These elements can then be merged with the SES framework, either falling under existing second tier variables, or adding new ones as needed to better define the environmental public goods dilemma context. Working up from actor perceptions of their own behavior and experience to the system level will allow analysts to identify institutions and contextual variables shaping system outcomes in environmental public goods dilemmas.

Ultimately these two recommended approaches to strengthening the institution-behavior link can be used in conjunction, or iteratively to improve our understanding of institutional design in environmental public goods dilemmas.

Conclusions

The study of environmental public goods dilemmas and of diverse institutional arrangements can help us to identify design principles to improve the sustainability of these regimes. The SES framework was designed with the ambition to fill this need and facilitate the study of all types of SES. However, in application, the SES Framework has struggled to facilitate the study of SES beyond CPR regimes and community-based natural resource management institutions. The same attributes of environmental public goods dilemmas that differentiate them from CPR regimes, namely the lack of a behavioral feedback, the multi-actor and multi-resource system dynamics, higher levels of uncertainty and complexity, and lack of built-in social capital, also increase the need to understand how a broader suite of institutions govern these systems. I have proposed that one way to address these linked challenges within the SES framework and facilitate the application of the SES to these types of systems is to expand the framework's focus on the institution-behavior link. I suggest that this can be done through incorporating decision-making and behavioral models from psychology and behavioral economics into the SES framework and through examining actor mental models to define relevant system attributes. Both of these recommendations will improve the ability of the SES framework to accommodate the analysis of more diverse resource regimes and facilitate the design of context-specific, adaptive institutional interventions to support sustainable resource management.

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