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Uncertainties in demonstrating environmental benefits of payments for ecosystem services

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ABSTRACT

Payments for Ecosystem Services (PES) have become the flagship of conservation organizations in recent years. However, PES schemes are as much criticized as they are acclaimed in the literature. Researchers have pointed that many PES schemes, particularly water-related ones, are based on unreliable assumptions and lack strong causal links between land use and ecosystem services. Evidence of outcomes is hardly demonstrated. This uncertainty in PES schemes arises not only from practical difficulties, but from the complexity of the human-environment systems (HES), and the limits of current knowledge about HES. Many scientists and practitioners have proposed that more research is needed to improve the scientific basis of PES. Here we argue that this research should be complemented with a deeper understanding of the uncertainties involved in PES, an explicit treatment of these in the whole process of PES negotiation, design and monitoring, and clear uncertainty communication among the actors involved. Neglecting uncertainties could lead to unfounded expectations and poor assessments of PES outcomes. If recognizing and accounting for uncertainties are to threaten the success of PES, then uncertainty can be seen as an opportunity to open up the dialogue to alternative ways of achieving the desired conservation goals.

1. Introduction

Ecosystem Services (ES) have been considered one of the most prominent approaches towards conservation nowadays (Kull et al., 2015). With roots in the late 1970s and strong influence from neoclassical economics (Barnaud and Antona, 2014; Gómez-Baggethun et al., 2010), the concept has travelled in the hands of economists and ecologists and reached policy spheres by means of concrete practices (Costanza et al., 1997; Costanza and Daly, 1992; Daily, 1997; de Groot, 1992; Millenium Ecosystem Assessment, 2003). Accordingly, mechanisms derived from the ES concept – like Payments for Ecosystem Services (PES) – have become the flagship of many conservation organizations and have been pitched, among other things, as solutions for lack of funding and inefficiency (Ferraro and Simpson, 2002; Postel and Thompson, 2005).

While, on the one hand, PES schemes have been positioned as an alternative solution for conservation, on the other hand, increasing criticism ranging from the very conceptual roots of ES to the social and environmental trade-offs found in practice has paralleled the increasing trend of implementation of PES projects (Dempsey and Robertson, 2012; Kosoy and Corbera, 2010; Kull et al., 2015; Muradian et al., 2010; Norgaard, 2010; Peterson et al., 2010). The criticism rests in part on the observation that many PES schemes are based on untested assumptions, e.g. related to the role of vegetation on hydrological services (Lele, 2009; Ponette-González et al., 2014), and have critical information gaps, such as baseline data and definition of the target ecosystem service (Carpenter et al., 2009; Martin-Ortega et al., 2013; Naeem et al., 2015; Ojea and Martin-Ortega, 2015). PES projects have also been criticized for a lack of robust monitoring and evaluation processes (Echavarria et al., 2004; Muradian et al., 2010; Porras et al., 2008; Postel and Thompson, 2005).

In sum, there are considerable uncertainties in demonstrating the environmental benefits of PES promised on paper. Uncertainty is here understood as "any deviation from the unachievable ideal of completely deterministic knowledge of the relevant system" (Walker et al., 2003, p.5). If, as a consequence, environmental benefits fall short of expectations or are not even detected, then this

Abbreviations: ES, ecosystem services; PES, payments for ecosystem services; HES, human-environment systems; PWS, payments for watershed services.

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puts under risk the trusting relationships among the actors built to support the PES schemes, the reputations of the organizations involved, and the long term conservation efforts (Fisher and Brown, 2014; Muradian et al., 2010).

To some, the solution to uncertainty is straightforward: More scientific research (Kaimowitz, 2005; Kosoy et al., 2007; Naeem et al., 2015). Accordingly, Naeem et al. (2015) have written a set of guidelines to "get the science right" in PES schemes; baseline data to document initial conditions and a monitoring system are among its fundamental principles. However, uncertainty will not disappear with more science, and we might even create uncertainty as we discover new limits to our knowledge or leave whole research strands unexamined by focusing narrowly on the "right science" (Brown, 2010; Gross, 2010; Stirling, 2010; Wynne, 1992). The transaction costs of "getting the science right" may also prove prohibitive for a scheme to work properly (Muradian et al., 2010; Wunder, 2008).

PES schemes will thus have to "live with uncertainty", and a thorough evaluation and communication of uncertainty seems mandatory (Hamel and Bryant, 2017). With this paper we take a step towards these goals with respect to water related PES by inventorying the sources and types of uncertainty according to three fundamental uncertainty factors (Norgaard, 2010; Muradian et al., 2010; Barnaud and Antona, 2014): (a) the *complexity* of human-environment systems (HES); (b) the *limits of knowledge* about these systems; and (c) *practical constraints*, such as the high cost of measuring and monitoring system variables. We thereby complement the existing political economy/political ecology critiques of ES governance by bringing in literature on uncertainty in Hydrology and more general ignorance studies, and draw on a case study in Colombia to illustrate our points.

The article proceeds as follows: Section 2 discusses how HES complexity may preclude evidence of environmental benefits of PES; Section 3 reviews the limits of available scientific knowledge regarding the links between land cover and hydrological services, and explores the sources of uncertainty in knowledge production itself; Section 4 details several practical constraints of PES schemes; Section 5 presents the illustrative case study; and in Sections 6 and 7 we discuss the previous points and conclude with some propositions on how to consider uncertainty in PES schemes and the prospects of adaptive approaches.

2. Complexity

PES schemes are part of complex HES that are composed of a myriad of elements and subsystems interacting dynamically and exhibiting non-linear and emergent properties that can only be properly observed and understood when taking into consideration the system as a whole (Liu et al., 2007; Ostrom, 2009). HES are constantly evolving through exchanges of energy, matter, and information (Liu et al., 2015). They are open, multidimensional, dynamic, multi-scalar, spatially distributed, multi-agent, multi-causal, and therefore exhibit conditions that are very site-specific (Biggs et al., 2009; Brown, 2010; Liu et al., 2015, 2007; Ostrom, 2009). All these features render HES predictions inherently uncertain and make PES schemes, like other conservation initiatives, difficult to be designed, implemented and successfully managed in practice.

As HES are *open* systems, any boundaries established to study and manage HES are artificial. Drawing these boundaries is informed by the perceived problems and solutions and will, in turn, reinforce these very same problems and solutions (Brown, 2010). Examples of such artificial boundaries are the "area of influence" of PES schemes (theoretically, the area in which both service users and providers are located), and even economic boundaries like "ES provider" and "ES user". As designing conservation interventions inevitably draws boundaries, schemes like PES will always face external influences or surprises due to unexpected system behavior or neglected processes.

HES involve interacting processes in a *multidimensional* setting. Groundwater flows are connected to surface water flows, conditioned by climate inputs and controls in the form of precipitation, wind, temperature, and other factors. These flows are mediated by soil conditions and land cover, subject to human influence. Land use is a product of social-cultural, institutional and economic conditions together with geomorphology and soil characteristics, like fertility and porosity. PES schemes may fail if these dimensions are not considered together.

Because HES are *multi-scalar*, i.e. they are *temporally dynamic* and *spatially distributed* (Liu et al., 2015, 2007), PES schemes are subject to the timing, frequency, amplitude, and nested scales of processes in these systems. It is often difficult to detect and investigate environmental changes at the scale of interest (Biggs et al., 2009). For instance, in a watershed context, river discharge and its sediment load are products of cumulative processes involving the entire watershed as well as the climate system, which means the ES in this case cannot be framed in terms of land units like farms (Barnaud and Antona, 2014). It will be difficult to assess the overall impact of conservation if only part of the land owners in a watershed engages in the conservation practices. In a voluntary scheme, those land owners whose properties contribute most sediment or contaminant loads to the streams might be completely missed. And if monitoring is only carried out at the mouth of the main river in the watershed, it is difficult to isolate the effect of conservation practices from other human interventions or natural effects taking place in the different tributaries.

As HES are *multi-agent* systems, different types of individuals, groups and social networks interact with each other and change the system through competition, cooperation, hierarchies, association, etc. (Barnaud and Antona, 2014). Not accounting for the social networks, power relations and conflicts in place can negatively influence PES effectiveness. For instance, the conservation practices of farmers may not be effective in guaranteeing water quality if local industries, even acting as payers for on-farm schemes, continue to act as a source of water pollutants (e.g. Rodriguez-de-Francisco and Budds, 2015). In some cases, the dichotomy "provider-payer" may create unbalanced power relations, with payers or intermediaries defining rules disregarding providers' standpoints, which may be used for short term gains, e.g. political power or green marketing, rather than improving ES.

As most of the processes occurring in HES are *multi-causal* and not all the causes are controlled by human intervention, it does not make sense to assess causes in isolation (Biggs et al., 2009). For instance, high levels of arsenic in water can be a result of geochemical site characteristics (Nordstrom, 2002). And certain river basins can produce impressive amounts of sediment purely as a result of their geomorphology and precipitation patterns (e.g. Restrepo et al., 2006). If causal links are not well understood, especially biophysical processes generating ES (Palmer and Filoso, 2009), PES schemes may propose solutions based on processes that are not actually under human control and, therefore, end up being considered ineffective and mistrusted (Ponette-González et al., 2014).

The aspects of HES complexity discussed in this section make ES provision extremely *site-specific* (Biggs et al., 2009). We now proceed by exploring how the limits of our current understanding of HES and the uncertainties related to knowledge production may affect our ability to predict and verify environmental outcomes of PES in particular places.