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Effectiveness and Uncertainties of Payments for Watershed Services

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Leticia S. Lima

Abstract

Payments for Ecosystem Services (PES) have become the flagship of conservation organizations in recent years. The idea of securing ecosystem service (ES) provision through PES has been present in practical discourses of intermediaries directed at potential payers. However, demonstrating that PES can actually achieve the intended goals has been difficult for practitioners. Researchers have pointed out that many PES schemes, particularly water-related ones, are based on unreliable assumptions and lack strong causal links between land use interventions and ecosystem services. This uncertainty in PES schemes arises not only from practical difficulties, but from the complexity of human-environment systems (HES), and the limits of knowledge about them. Researchers have been able to describe and discuss these major challenges. However, the literature is still poor on empirical studies exploring the additionality of PES schemes, that is, if those schemes produce additional effects not attributable to other factors, as well as studies exploring the importance of impact evidence for stakeholders involved. This dissertation contributes to filling this empirical gap by exploring four water-related payments schemes (here also called payments for watershed services, PWS) in Colombia, comparing the cases in terms of their efforts to produce impact evidence through monitoring and evaluation, and their associated challenges. Three cases from Brazil are also included in one of the chapters and compared with the Colombian cases by illustrating differences and similarities. This dissertation aims to understand the role that scientific uncertainty plays in the effectiveness of PWS schemes, i.e. in the actual achievements in terms of the goals of improving or maintaining the target ecosystem services. It also addresses the importance of impact evidence for the permanence of stakeholders, such as ES providers and payers, in the scheme. The results show that most of the PES payers' respondents have additional motivations other than ES provision for engaging in PES schemes and would not disengage if effectiveness is not demonstrated. However, they do require indicators from intermediaries related to the activities performed. Most of the providers interviewed declared that they would have engaged in the PES scheme even without economic incentives because they are concerned with protecting water resources for their own sake. It turns out that intermediaries are the ones most concerned with presenting evidence of PES additionality for reasons such as securing future funds and sustaining trust relationships with other

stakeholders. In most cases studied here, monitoring and evaluation design did not start at the implementation stage, but were added at later stages, possibly as a response by the organizations promoting or managing PES schemes to the recent debates on the actual impact of PWS schemes on water resources. This dissertation argues that impact evaluation 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.

Keywords

Payments for Ecosystem Services; Ecosystem Services; Water; Complexity; Human-environment system; Colombia;

Zusammenfassung

Zahlungen für Ökosystemdienstleistungen (Payments for Ecosystem Services, PES) sind in den letzten Jahren zum Aushängeschild von Umweltorganisation geworden. Der Gedanke, die Bereitstellung von Ökosystemdienstleistungen durch PES abzusichern, ist in praktischen Diskursen von Vermittlern zu finden, die an potentiell Zahlende gerichtet sind. Praktikern ist bisher jedoch schwer gefallen, zu zeigen, dass PES tatsächlich zu den vorgesehenen Zielen führen können. Forscher haben darauf hingewiesen, dass zahlreiche PES-Schemata, insbesondere diejenigen mit Bezug auf Wasser, auf unsicheren Annahmen beruhen und außerdem gewichtige Kausalzusammenhänge zwischen Eingriffen in die Landnutzung und Ökosystemdienstleistungen vermissen lassen. Diese Unsicherheit in PES-Schemata geht nicht nur aus praktischen Schwierigkeiten hervor, sondern aus der Komplexität von Mensch-Umwelt-Systemen (human-environment systems, HES) und aus der Begrenztheit des Wissens über diese Systeme. Forscher sind zwar in der Lage, diese wesentlichen Herausforderungen zu beschreiben und zu diskutieren. In der Fachliteratur mangelt es jedoch an empirischen Studien, die die zusätzliche Wirksamkeit von PES-Schemata untersuchen, d.h. ob diese Schemata zusätzliche Wirkungen zeigen, die anderen Faktoren nicht zurechenbar sind, bzw. Studien, die die Bedeutung von Nachweisen für ihre Wirksamkeit für die Interessengruppen (stakeholders) untersuchen. Die Dissertation trägt dazu bei, diese empirische Lücke zu schließen: Dazu untersucht sie vier wasserbezogene Zahlungsschemata, hier auch Zahlungen für Wassereinzugsgebietsleistungen (payments for watershed services, PWS) genannt, in Kolumbien. Sie vergleicht die vier Fälle hinsichtlich der Bestrebungen, durch Beobachtung (monitoring) und Evaluation Nachweise für die Wirksamkeit zu erbringen, sowie hinsichtlich der damit verbundenen Herausforderungen. Eines der Kapitel enthält auch drei Fallstudien aus Brasilien, die als Vergleich zu den Fällen aus Kolumbien und der Darstellung von Unterschieden und Gemeinsamkeiten dienen. Diese Dissertation hat zum Ziel, die Bedeutung wissenschaftlicher Unsicherheit für die Wirksamkeit von PWS-Schemata zu verstehen, d.h. für die tatsächlichen Erfolge in Bezug auf das Vorhaben, Zielökosysteme zu erhalten oder zu verbessern. Sie setzt sich darüber hinaus auch mit der Bedeutung von Wirksamkeitsnachweisen für den Verbleib der Stakeholder (vorrangig ES-Träger und Zahlende) im PES-Schema auseinander. Die Ergebnisse zeigen, dass die meisten Befragten aus der Gruppe

der PES-Zahlenden nicht nur aufgrund der Bereitstellung von Ökosystemdienstleistungen, sondern auch auf andere Weise motiviert sind, sich an PES-Schemata zu beteiligen, und dass sie ihre Beteiligung nicht beenden würden, sollte ihre Wirksamkeit nicht nachgewiesen werden. Von Vermittlern fordern sie dennoch Indikatoren für durchgeführte Maßnahmen. Die meisten der befragten Träger gaben an, dass sie sich auch ohne wirtschaftliche Anreize an einem PES-Schema beteiligt hätten, da sie sich um ihrer selbst willen um den Schutz von Wasserressourcen bemühen. Es stellt sich heraus, dass die Gruppe der Vermittler diejenige ist, die sich am meisten damit befasst, Nachweise für die zusätzliche Wirksamkeit von PES zu präsentieren, um dadurch zukünftig Geldmittel zu sichern bzw. um Vertrauensverhältnisse mit anderen Interessengruppen aufrecht zu erhalten. In den meisten hier untersuchten Fällen wurden Beobachtung und Evaluation nicht anfänglich ab der Einführung des jeweiligen PES-Schemas durchgeführt, sondern erst in späteren Phasen, möglicherweise als Antwort der Organisationen, die PES-Schemata fördern und verwalten, auf die jüngsten Diskussionen über die tatsächlichen Auswirkungen von PES-Schemata auf Wasserressourcen. Diese Dissertation argumentiert für die Ergänzung der Evaluation von Auswirkungen durch eine tiefergehendes Verständnis der mit PES verbundenen Unsicherheiten, eine explizite Bearbeitung dieser Unsicherheiten im gesamten Verlauf von PES-Verhandlung, -Gestaltung und –Beobachtung, und eine klare Kommunikation über Unsicherheiten unter den beteiligten Akteuren.

Schlagwörter

Zahlungen für Ökosystemdienstleistungen; Ökosystemdienstleistungen; Komplexität; Mensch-Umwelt-System; Kolumbien;

Content

List of Tables

List of Figures

List of Acronyms and Abbreviations

AMVA – Área Metropolitana del Valle de Aburrá
ANA – Agência Nacional de Águas
ASOBOLO – Asociación de los Usuarios de Agua del Río Bolo
ASOCAÑA – Asociación de Cultivadores de Caña de Azúcar de Colombia
CATI – Coordenadoria de Assistência Técnica Integral
CENICAÑA – Centro de Investigación de la Caña de Azúcar de Colombia
CIAT – Centro de Investigación para la Agricultura Tropical
CIPAV – Centro para la Investigación en Sistemas Sostenibles de Producción Agropecuaria
CORANTIOQUIA – Corporación Autónoma Regional del Centro de Antioquia
CORNARE – Corporación Autónoma Regional de las Cuencas de los Ríos Negro y Nare
CSAH Cali – Compensación por Servicios Ambientales Hídricos de la Cuenca del Río Cali
CSR – corporate social responsibility
CVC – Corporación Autónoma Regional del Valle del Cauca
DAGMA – Departamento Administrativo de Gestión del Medio Ambiente de Cali
DSUMA – Departamento de Serviços Urbanos e Meio Ambiente da Prefeitura de Extrema
EESC/USP – Escola de Engenharia de São Carlos / Universidade de São Paulo
EAAB – Empresa de Acueducto, Alcantarillado y Aseo de Bogotá
EMCali – Empresas Municipales de Cali
EPM – Empresas Públicas de Medellín
ES – Ecosystem Services
FAVS – Fondo Agua Por la Vida y Sostenibilidad
FEMSA – Fomento Económico Mexicano
GEF – Global Environment Facility
HES – Human-Environment Systems
IADB – Inter-American Development Bank
Ibio – Instituto BioAtlântica
ICDP – Integrated Conservation and Development Project
IDAF – Instituto de Defesa Agropecuária e Florestal do Espírito Santo
IEF/MG – Instituto Estadual de Florestas de Minas Gerais
IEMA – Instituto Estadual de Meio Ambiente e Recursos Hídricos do Espírito Santo
INCAPER – Instituto Capixaba de Pesquisa, Assistência Técnica e Extensão Rural
LULC – land use and land cover
MA – Millennium Ecosystem Assessment
PES – payments for ecosystem services, used here as similar term for payments for environmental services.
PCJ – Comitê das bacias hidrográficas dos Rios Piracicaba, Capivari e Jundiaí
PWS – payments for watershed services
RD – river discharge
SDA – Secretaria Distrital de Medio Ambiente de Bogotá

SEAMA – Secretaria de Estado de Meio Ambiente e Recursos Hídricos do Espírito Santo
TNC – The Nature Conservancy
NGO – non-governmental organization
UNAL – Universidad Nacional de Colombia
USAID – United States Agency for International Development
WQ – water quality
WWF – World Wildlife Foundation

Abbreviations used for Water Quality Parameters

TEMP – temperature
DO – dissolved oxygen
BOD – biochemical oxygen demand
COD – chemical oxygen demand
DOM – dissolved organic matter
TS – total solids
TDS – total dissolved solids
TSS – total suspended solids
TSED – total sedimentable solids
TH – total hardness
EC – electrical conductivity
AC – alkalinity
PHO – total phosphorus
NIT – total nitrogen
NO_2^- – Nitrite ion
NO_3^- – Nitrate ion
COL – coliforms
Mn^{+2} – Manganese (2+) ion
Mn^{+4} – Manganese (4+) ion
Cl^- – Chlorine ion
Na^+ – Sodium ion
Fe^{+2} – Iron (II) ion
Fe^{+3} – Iron (III) ion

Dissertation Roadmap

The present dissertation is organized in the following structure:

Chapter 1, Introduction, presents the **context** of the study, the research questions and the case studies included in the dissertation. It also provides an overview of the fieldwork and data collection.

Chapter 2 presents the **theoretical background** for the dissertation and is dedicated to explore important concepts and their origins in order to support the reader in navigating through the following chapters. It starts with some basic concepts from Hydrology and Institutional Economics, moves on to the origins of ecosystem services (ES) and payments for ecosystem services (PES), and concludes with some concepts from Ignorance and Uncertainty studies.

Chapter 3 presents the **1st scientific article**, entitled "Uncertainties in demonstrating environmental benefits of payments for ecosystem services". This article offers a conceptual overview of uncertainty sources in PES and illustrates the main arguments with a brief case study.

Chapter 4 presents the **2nd scientific article**, entitled "Efforts and constraints to demonstrate additionality of payments for watershed services. Insights from Colombia and Brazil" This empirical study explores technical and institutional aspects of seven PWS schemes in their quest for demonstrating impact evidence of their conservation interventions and the respective constraints that can be found in practice.

Chapter 5 presents the **3rd scientific article**, entitled "Will PES schemes survive in the long-term without evidence of their effectiveness? Exploring four water-related cases in Colombia." This article explores the perspectives and expectations of different stakeholder groups in PWS schemes regarding the evidence of the project impact, i.e. its effectiveness.

Chapter 6 presents the **synthesis and conclusion**, followed by a list of all references cited in this dissertation.

1 Introduction

This introduction presents a general overview of the importance of water for all living beings, including humankind in its multidimensional expressions. Subsequently, the context and objectives of this dissertation are presented and related to the core research questions, the explored cases and the fieldwork conditions for empirical data collection.

1.1 Water for Life

Water is a fundamental component of the planet and all living beings. Even the simplest form of life depends on water for survival, since an infinite number of chemical reactions needed to support life would not occur without it (Smith and Smith, 2000). Water bodies like rivers, lakes, and oceans, are home for an uncountable number of forms of life interacting in complex ecological relations in riverbeds, mangroves, deltas, coastal areas, coral reefs, etc. (Smith and Smith, 2000; Ward et al., 1999). It is therefore, not surprising that several ancient civilizations flourished close to water bodies or developed their strategies to obtain groundwater (Priscoli, 2000; Vuorinen et al., 2007). Fisheries, crops, cattle ranching, and sanitation all depend on this important resource.

Water has been such a central component of human societies that its meanings transcend those related to the pure physical human needs. It is at the heart of a large number of cultural expressions like myths, songs, and rituals (e.g. Garcia, 2007; Miranda et al., 2014). It is an essential part of several religious cosmologies (Vuorinen et al., 2007). It is present, for instance, in many Christian stories from the Old and New Testaments. In the Hindu traditions, the rivers play an enormous role in death rituals, in which the believer's body is released to float downstream. In the Greek mythology, two rivers divide the world of the living ones from that of the dead and a boatman must carry every soul across them (Garcia, 2007). Yemanjá, the most iconic Afro-Brazilian deity, is the symbol of fertility and is originally associated with the sea and fisheries (Mason, 2016; Miranda et al., 2014; Rangel and Gomberg, 2016). In Colombia, the lakes formed in very high altitudes in the Paramos' ecosystems were sacred places for the ancient Muisca people and gold offerings were frequently thrown into the lakes as part of religious rituals (Legast, 2000).

Such an important role played by the water can also determine the fate of many societies. Droughts and long dry periods have forced many communities around the world to migrate or led to their decline (e.g. Haug et al., 2003). Disputes over water sources for consumption, transportation or territorial domain have been associated with intense conflicts (Jerome Delli Priscoli and Aaron T. Wolf, 2010). As water is essential for food production, its scarcity could mean dependence over food imports from other countries (Brown, 2011; Ward et al., 2015). Governments also face the challenge to come up with diplomatic solutions for the common use of transboundary rivers and aquifers (Dinar, 2008). The challenges related to water resources availability, use, and management are many (Vörösmarty et al., 2010); e.g. water use demands and its spatial distribution (Wada and Bierkens, 2014), urbanization and floods (Hollis, 1975), land use and its impacts on the water quality and quantity (Bruijnzeel, 1990).

In order to address these social challenges, norms and rules on the use of land and the use of water have been proposed in a variety of contexts throughout the years. From integrated watershed management approaches (FAO, 2006), over taxes related to 'polluter pays' principle (Howarth, 2009) and land-surface zoning (Adams and Foster, 1992), to the more recently proposed Payments for Watershed Services (PWS) (Asquith and Wunder, 2008; Porras et al., 2008; Smith et al., 2006), there is nowadays a large number of institutional attempts to deal with water management problems in a variety of contexts and scales. This dissertation focuses on the last mentioned mechanism, PWS.

This very brief overview is a starting point to contextualize the problematics at hand, the rationale of the present study and to introduce the research questions, as it follows.

"The history of social organization around river basins and watersheds is humanity's richest records of our dialogue with nature. It is among the most fertile areas for learning about how the political and technical interact. The spatial and functional characteristics of the river basins influenced human settlement and interaction long before the idea of the river basin started to be formalized into legal and administrative terms. The direction of flow of rivers influenced the movement of civilization. Rivers have been crucial to means of communication leading to the formation of political units." - Jerome D. Priscoli (2000, p. 623)

1.2 Context and Research Questions

In the recent decades, the idea of directly paying rural land owners to adopt certain conservation practices in order to protect natural resources, such as water, has gained strength after claims that another popular community-level approach, called Integrated Conservation and Development Projects (ICDPs)[1], was not achieving the expected results in developing countries (Ferraro and Kiss, 2002). The idea of *direct payments for conservation* was already present in the United States and Europe by the end of the 1990's (e.g. European Commission, 2005). It was portrayed as a more advantageous approach because governments were seen as failing to enforce conservation by law and indirect approaches, such as ICDPs, were considered inefficient due to a lack of control of the expected links between local development and desired environmental outcomes (Ferraro and Kiss, 2002; Ferraro and Simpson, 2002). Based on these calls and through the promotion of so-called 'successful' payment cases – either in the form of national programmes (Pagiola, 2008) or led by non-government actors (Perrot-Maître, 2006) – several international organizations and development agencies promptly begun to invest in those more direct conservation approaches that would be later called 'Payments for Environmental Services', or 'Payments for Ecosystem Services' (PES).

However, the advantages of such an approach started to be questioned as soon as it gained strength. With a long list of points of criticism (e.g. Barnaud and Antona, 2014; Farrell, 2014; Kull et al., 2015; Pascual et al., 2014; Robertson, 2012, 2006), a number of researchers questioned the most cited PES definition (in Wunder, 2007, 2005) and the assumptions underlying it (Lele, 2009; Muradian et al., 2010; Sommerville et al., 2009). This most cited

[1] ICDPs were a popular approach for conservation in the 1980-90's proposed as a way to achieve conservation in low-income countries by investing in sustainable production projects with communities living close to strategic areas for natural resources, such as protected areas (Peters, 1998; Wells et al., 1999).

definition of PES proposes that PES is a voluntary transaction that involves paying for a 'well-defined' environmental service (ES)[2] or a land use 'likely' to secure the service, and that the transaction should be done only if the service 'provider' secures service provision – the conditionality criterion (Wunder, 2005). As Wunder (2005, p. 3) pointed out, the word 'likely' refers to the existence of "important scientific insecurities" [sic], that in the case of water-related PES (here called 'payments for watershed services' - PWS) mainly relates to the uncertainties around the links between land use and watershed dynamics, such as streamflow and processes influencing water quality (Kosoy et al., 2007; Lele, 2009; Lima et al., 2017).

As Muradian et al. (2010, p. 1204) put it, "the context in which most PES schemes operate is often characterized by high uncertainty in the accountability of environmental services provision, due to the biophysical complexities associated with the relationships between land use and such services". In practice, many PES schemes have been implemented without a strong causal relationship between the land use practices and the ES (Barnaud and Antona, 2014; Lele, 2009; Muradian et al., 2010), meaning that the conditionality criterion is not met in most cases. As this situation is particularly critical in the case of PWS schemes, proxies such as total forest area under protection and number of trees planted, instead of ES outcomes, have been frequently used by practitioners to demonstrate conditionality (Ponette-González et al., 2014; Porras et al., 2008; Quintero et al., 2009; Wunder, 2005). Because many PES schemes – especially in PWS cases – lack a demonstrable foundation, researchers have been pointing out that they may be based more on 'faith' rather than on empirical knowledge (Fisher et al., 2010; Kosoy et al., 2007; Muradian et al., 2010; Tallis et al., 2008; Wunder, 2007).

Such concerns have led several scientists and conservation practitioners to advocate for more and better science to support PES (Naeem et al., 2015). However, it remains unclear if more science in itself will ensure the success of PES. A better science for PES would need to be able to not only demonstrate *conditionality*, but also present evidence of *additionality*, i.e. evidence that the observed environmental changes are clearly due to conservation practices and not to other factors, as widely advocated by environmental economists (Baylis et al., 2015; Boerner et al., 2017; Ferraro, 2009; Ferraro and Pattanayak, 2006). The implications for PES schemes

[2] In this dissertation "payments for ecosystem services" is used as a similar term for "payments for environmental services", since they are commonly used in the literature as synonyms (Wunder, 2013).

may be important: Assuming that one motivation for actors to engage as 'payers' in PES is linked to their expected return from the maintenance or improvement of the desired ES, how to sustain the actors' commitment to the payments in the face of *uncertainty*? As Wunder (2005, p. 3) put it, "the less realistic the scientific basis of a PES scheme, the more exposed it is to the risk of buyers questioning its rationale and abandoning payments."

If environmental outcomes of the conservation practices fall short of expectations or are not even detected, then this puts under risk (a) the trusting relationships among the actors built to support the PES schemes, (b) the reputations of the organizations involved, and (c) the long term conservation efforts (Fisher and Brown, 2014; Muradian et al., 2010). Therefore, neglecting uncertainty in PES schemes can ultimately lead to a decrease in funding and a potential failure of the schemes in the long term. If the reputation of the PES proponents is damaged as well, then the funding for alternative conservation programs beyond PES may be at risk too (Fisher and Brown, 2014; Lele, 2009). Therefore, the confidence actors have in a particular scheme, their support, and permanence are fundamental for the long-term continuity of such projects.

In this context, one could ask if the ultimate origin of the "impact evidence problem" is just a matter of lack of proper *science*, as it appears to be conveyed in Naeem et al. (2015). Another possibility would be that this 'evidence-based thinking', these promoted scientific best practices, and the very conceptual roots of PES, are quite distant from the reality conditions. This way of framing conservation appears to assume that there is a way of doing the 'right science' (Barnaud and Antona, 2014), that we can separate desired components of the environment as pieces of a machine (Robertson, 2012), and that we can control field conditions almost as in a laboratory in order to produce the desired *evidence*. On the basis of these issues, this dissertation extends this debate with the objective of exploring the role of scientific uncertainty on the *effectiveness* of water-related PES (PWS) schemes, i.e. on the actual achievements in terms of the goals of improving or maintaining the target ecosystem services. It also addresses the role of evidence in the permanence of stakeholders, such as ES providers and payers, in the scheme.

1.2.1 Research Questions

Considering all these aspects, this dissertation focuses on **three general research questions** that are addressed in each of the three scientific papers that compose this dissertation:

(1) What are the sources and types of uncertainty that affect and may undermine the evidence of expected environmental outcomes of payments for watershed services?

> With this research question, the potential sources of uncertainty that may be typical of the knowledge production process, and the practical constraints commonly found in the field are objects of inquiry, in addition to the lack of knowledge on land-water links.

(2) Why most PWS schemes reported in the literature have been unable to provide evidence of the effectiveness of their schemes so far?

> This research question concerns the conditions in which current PWS schemes operate to produce evidence of their environmental impacts and the challenges that practitioners may face in the field that constrain their ability to demonstrate the impacts.

(3) What are the expectations and perceptions that different actors have regarding the effectiveness of PWS schemes?

> This research question is centered on the potential effects that the evidence of effectiveness or its absence could have on involved actors and how it could modulate their participation in the scheme. Additional potential motivations to participate are also part of this inquiry as a way to verify if the presence of those motivations could change the value placed on the evidence of effectiveness.

In order to address these questions, this dissertation explores four PWS cases in Colombia and, in one specific study, includes three other cases from Brazil as a comparative in Latin America, using data collected by one of the co-authors of the referred study (Chapter 4). In the following sub-section, the context of the studied PWS initiatives in Colombia is briefly described.

1.2.2 Case studies

Latin America is known worldwide by the large number of PWS cases, and has pioneered several of these projects (Echavarria, 2002; Echavarria et al., 2004; Pagiola, 2008). In a review, Martin-Ortega et al. (2013) found 40 cases of PWS in Latin America from 1984 to 2011. The first Latin-American PWS cases, although not named this way at the time, begun to appear in the early 1990's in Colombia. In the beginning of the 1990's, several water users associations were created in the Valle del Cauca, Colombia, with the intention to promote conservation of upstream catchments that release water used in the large sugarcane plantations of this valley (Echavarria, 2002). The users organized themselves in associations supported by the local environmental authority (*Corporación Autónoma Regional del Valle del Cauca* – CVC) and started paying a regular voluntary fee that would be then used to implement conservation practices in the upstream areas (Lima et al., 2017; Munoz Escobar et al., 2013; Rodriguez-de-Francisco and Budds, 2015). Landholders in the upstream catchments would also engage in a voluntary basis receiving incentives that would improve farm conditions and help them producing more sustainably. Nowadays, there are around 15 associations of the same kind in the Valle del Cauca (Moreno-Padilla, 2016).

During the mid-2000's another approach to gather funds to protect watersheds based on similar ideas started to gain strength in Latin America through joint efforts between government bodies and civil associations: the *water funds*. A water fund is a concept widely promoted by the non-governmental organization (NGO) The Nature Conservancy, and it is defined as a financial mechanism involving multiples sectors in a form of a trust fund to promote watershed conservation (Calvache et al., 2012). Interested organizations and water users engage voluntarily and the funds that are collected are reinvested in order to have a self-sustained mechanism in the long-term. The funds are used for conservation activities in the upstream areas of the watersheds that are strategic for the water provision of large cities (R. L. Goldman et al., 2010). In Colombia, this model was initially implemented in the city of Bogotá. Launched in 2009, the "Agua Somos" fund was the first of what are now four funds currently working in different Colombian regions, with several others under development (Goldman-Benner et al., 2012). The association of sugarcane producers in the Valle del Cauca Department (ASOCAÑA), together with the above-mentioned water user associations, created their own water fund in 2009, called *Fondo Agua Por la Vida y Sostenibilidad* (FAVS) (Moreno-Padilla, 2016).

In this dissertation, four Colombian cases are explored in a series of three studies. These cases include the above-mentioned "Agua Somos" (Goldman-Benner et al., 2012); a conservation scheme led by the water users association of Bolo River – "ASOBOLO" (*Asociación de Usuarios de Agua del Río Bolo*), which is supported by FAVS (Munoz Escobar et al., 2013); "CSAH Cali", an environmental services compensation scheme (*Compensación por Servicios Ambientales Hídricos de la Cuenca del Río Cali*) (Fondo Patrimonio Natural et al., 2014); and "CuencaVerde", another conservation scheme following the water fund model (de la Ossa-Posada and Montoya-Velilla, 2017; Gómez-Ochoa, 2016). Because each PWS scheme is carried out in a large area encompassing more than one watershed, one or two watersheds were selected per scheme for the purposes of this doctoral research. The selected area in each case is the following (Figure 1-1):

- Agua Somos: watersheds of the rivers Chisacá and Mugroso, tributaries of Tunjuelo river; located in Usme, Bogotá D.C.;
- ASOBOLO: Aguaclara watershed - tributary of Bolo River; located in Pradera and Palmira municipalities, Valle del Cauca Department;
- CSAH Cali: watersheds of the rivers Felidia and Pichindé, tributaries of Cali River; located in the municipality of Cali, Valle del Cauca Department;
- CuencaVerde: watershed of Chico River, tributary of Riogrande River; located in Belmira municipality, Antioquia Department.

Technical and institutional details for each scheme, such as watershed area, activities performed, types of payments, number of providers, etc. are presented in the second and third scientific articles of this dissertation, on Chapters 4 and 5.

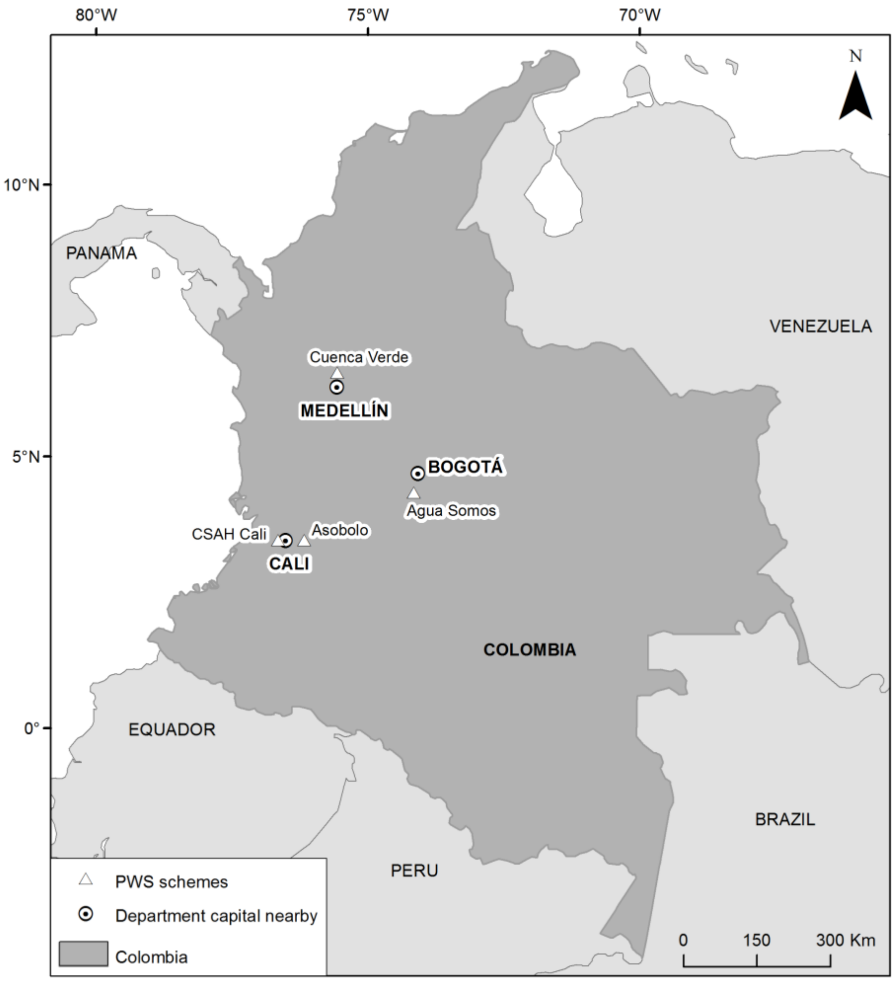

Figure 1-1: Location of the four Colombian PWS cases under study

The large number of early experiences of this kind in Colombia makes it an excellent study area to explore what has been done so far and what are the environmental outcomes of such initiatives.

In order to contrast experiences, the study aiming at exploring question 2 (presented in Chapter 4) includes Brazilian cases using secondary data obtained from published reports and papers, and data collected by Dr. Rafael Chiodi, a co-author in the referred study. The Brazilian cases illustrate how similar mechanisms have been developed in a Colombian neighbour country, and are valuable to explore similarities and differences between close contexts.

1.2.3 Fieldwork and data collection

In order to explore the four cases in Colombia, a preliminary field visit of two weeks was done in January 2015 to the cities of Bogotá and Medellín, followed by 6 months of fieldwork from January to July 2016 divided between the four case study sites. The preliminary field visit aimed at establishing a network of contacts and potential collaborators for the fieldwork. The fieldwork received support from the Faculty of Environmental and Rural Studies of the Pontificia Universidad Javeriana, Bogotá, where a 2-months research stay served as support for the data collection in the field. In addition, logistical support for the fieldwork was received from Fundación Patrimonio Natural, Asociación de Usuarios de Agua del Río Bolo (ASOBOLO), Asociación de Cultivadores de Caña de Azúcar de Colombia (ASOCAÑA), Centro de Investigación de la Caña de Azúcar de Colombia (CENICAÑA), Ecoforest SAS, and The Nature Conservancy (TNC).

Three stakeholders group were targeted in this research: PWS providers, also called 'sellers', i.e. rural landowners receiving payment for conservation; PWS payers, also called 'buyers' (Wunder, 2005), PWS managers and technicians. Managers and technicians are grouped into 'intermediaries', here understood as "those actors who take on roles that connect and facilitate transactions between buyers and sellers" (Huber-Stearns et al., 2013, p. 105). The fieldwork methods included semi-structured interviews, informal interviews, participant observation, and literature review of reports and related documents from the organizations managing and/or supporting the schemes, in addition to scientific papers describing the cases. Participant observation was done while following intermediaries work in the field (Figure 1-2) and by attending a major conference of PWS stakeholders involving 5 of the studied schemes among others from other countries (June 13th to 17th, 2016, Bogotá D.C.). All interviews were recorded, transcribed and had their content qualitatively analysed using NVivo software (QSR International Pty Ltd.) for coding. Following interviews, specific questionnaires based on the answers for the interviews were applied for each group, structured in questions that combined open and closed questions, selection of options, ranking, and degree of agreement with some statements. A Likert scale was applied for the agreement statements with a scale of 1 (mostly disagree) to 5 (mostly agree). The total number of interviews and applied questionnaires is reported in the study presented in Chapter 5.

Interviews involving PWS managers included questions regarding the reason why the scheme was created; the main actors involved in the initial design; motivations; and the status of the scheme in number of providers, activities performed, and total area committed for conservation so far. In addition, several questions were centred in the arguments used to engage both payers and providers; and then on the assessment of the effectiveness of the scheme, including the methods used for it, e.g. monitoring systems, case control and baseline data. Questions also included topics related to difficulties managers and technicians were facing in order to engage providers and payers, overcome institutional problems, obtain collaboration, and audit the scheme.

Questions that composed informal interviews with providers were related to their participation, contract conditions, satisfaction with the payments received, environmental perception of their territory and perceived changes connected with the PWS scheme. They were also questioned about their motivations to enter the scheme and their expectations regarding the environmental outcomes. Preliminary interviews were used to produce a questionnaire that was later applied to the providers. Payers of the related schemes were interviewed whenever possible; however, their availability for interviews was limited.

Most of the respondents from the intermediaries' group were from NGOs. Other respondents of this group included: representatives from local water users associations, representatives of other types of civil associations, researchers and technicians belonging to local research centres involved in monitoring PES schemes, and representatives from environmental authorities (Table 1-1).

Table 1-1: Characteristics of intermediaries' questionnaire respondents and their organizations. Individual and Organizations' non-exclusive roles in the scheme (n = absolute number of cases, % = percentage in terms of 25 respondents).

Individual Role in the Scheme	n (%)	Organizational Roles in the Scheme	n (%)*
Supporting Technician	9 (36)	Design	15 (60)
Manager	6 (24)	Support	14 (56)
Scientist in charge of research	5 (20)	Implementation	10 (40)
Mixed role: scientist/technician	2 (8)	Management	4 (16)
Mixed role: manager/technician	2 (8)	Evaluation	1 (4)
Other	1 (4)		

Professional Background	n (%)	Organizational Roles related to Monitoring	n (%)*
Biologist	7 (28)	Funding	15 (60)
Economist	4 (16)	Getting secondary data from third parts	15 (60)
Agricultural engineer	4 (16)	Direct monitoring of env. Indicators	14 (56)
Forest engineer	2 (8)	Logistics for monitoring in the field	13 (52)
Agronomy engineer	2 (8)	Processing monitoring data and report	13 (52)
Sanitary engineer	1 (4)	No role on monitoring	1 (4)
Environmental engineer	1 (4)		
Social worker	1 (4)		
Environmental manager	1 (4)		
Oceanographer	1 (4)		
Environmental technician	1 (4)		

Questionnaire and interview respondents belonging to the payers group were representatives of several types of organizations/firms: public water supply companies, private companies, government agency, and one development foundation. Among private companies, respondents were from: beverage, sugarcane and dairy production sectors, a restaurant, a health clinic, a lawyers firm, an infrastructure company and one service company. Respondents reported that their organizations provided payments of different kinds, including cash, materials, logistics and technical assistance to the schemes. Most of them are users of the water from the watershed in which their payments are invested for conservation (Table 1-2).

Table 1-2: Use of water from the watershed and type of payment by PWS payer; non-exclusive categories; n = absolute number of cases, % = percentage in terms of 15 respondents.

Use of water from the watershed	n (%)	Type of payment provided for the scheme	n (%)
Incorporated in products	7 (46.7)	Cash	13 (86.7)
Public water supply	4 (26.7)	Materials (e.g. construction, technology)	3 (20)
Private water supply	3 (20)	Logistic Services (e.g. transportation)	2 (13.3)
Use of water for industrial processes	4 (26.7)	Technical assistance (e.g. laboratory, GIS support)	4 (26.7)
No use of water	2 (13.3)	Other types	3 (20)
Other	1 (6.7)		

The providers group is composed mainly by landowners living in family farms inherited from relatives. Few respondents are not owners but long-term tenants. Most of the landowners have lived their entire life in the region, some of them in the nearby city. They are usually farmers who depend on their production as the main economic source. Cattle ranching is the most common use of land (Table 1-3).

Table 1-3: Characteristics of questionnaire respondents from the providers' group.

Scheme, Watershed	Providers		Characteristics of providers' respondents			
	number of agreements	number of respondents	Farm area average [median] (ha)	Most common type of property	Main land use	Avg. number of years with signed PES agreements
Agua Somos Chisacá/Mugroso	25	12	18.7 [7.1]	Inherited property	Cattle ranching, potato crops	2.2
ASOBOLO Aguaclara	56	30	8.8 [3.3]	Legally Acquired	Cattle ranching, fruit production	4.5
CSAH Cali Felidia/Pichindé	46	12	19.4 [4.5]	Legally Acquired	Fruits and herbs production, leisure, tourism	3.8
Cuenca Verde Río Chico	22	18	41 [8.5]	Inherited property	Cattle ranching	1.1

Table 1-3: continuation.

Scheme	Avg. Age	Most frequent gender	Avg. number of children	Avg. number of years living in the region
Agua Somos	61.8	male	3	55
ASOBOLO	54.0	Male	3	35.2
CSAH Cali	56.1	male	2	31.3
Cuenca Verde	53.1	male	3	44.6

Figure 1-2: fieldwork in Colombia. Observation of monitoring practices of PWS schemes. Source: Letícia Santos de Lima, Jan-June 2016.

"It is widely held that policymakers expect scientists to provide certainties and hence dislike uncertainty in the scientific knowledge base. But, uncertainty is a fact of life and a better understanding of the different dimensions of uncertainty and their implications for policy choices would be likely to lead to more trust in the scientists providing decision support, and ultimately to better policies."

- Walker et al., 2003, p. 6

2 Theoretical Background

This chapter presents an overview of important concepts that permeate the dissertation. It starts with a brief description of basic concepts in Hydrology, and some concepts related to management of natural resources; then moves to the origins of the ES concept and PES; and finally reviews basic concepts associated to policy evaluation, uncertainty and ignorance, and the role of uncertainty on impact evaluation and PES.

2.1 Intricate links between land and water

The amount of water that flows in a river can be estimated through the water inputs and outputs in the area delimited by the geomorphological divisions that converges the precipitation for a common river network, i.e. a watershed (Gupta, 2011). Precipitation and groundwater inputs feed the watershed, while evapotranspiration and groundwater outputs decrease the water availability. This balance would provide the conditions for the existence of springs, rivers, lakes, swamps, aquifers and other water bodies. The energy of the Sun is the main driver of the water cycle (Shaw et al., 2011), while the gravitational force and the physical properties of the environment, e.g. structure of rocks, soils, geomorphology and vegetation, modulate the water cycling. The solar energy is behind a large number of processes composing the weather patterns, and therefore, influences the inputs of water in a watershed through condensation and subsequent precipitation, and the outputs such as evaporation (Shaw et al., 2011). When precipitation reaches the surface, part of it is intercepted by the vegetation and other obstacles and can evaporate from there or accumulate and flow to the surface through trunks and other paths (Ward et al., 2015). Land cover also influences evapotranspiration: surface physical properties such as albedo and roughness will affect how solar radiation is absorbed or reflected by the surface and will have microclimatological effects (Bruijnzeel, 2004). Consequently, the water content of the vegetation, water bodies and first layers of soil is also affected.

When precipitation reaches the soil, geomorphological features together with edaphic conditions and vegetation cover will influence how much water will infiltrate to the ground, how much will flow through the surface, and what will be the water velocity during runoff (Araujo et al., 2005). Several physical properties play a role in these processes: types and position of rock layers; mineral composition, porosity and structure of the soil; amount of organic matter in the soil column; depth of plant roots; terrain slope and land cover; type of vegetation; microorganisms, etc. (Ward et al., 2015). The same properties also influence the water quality, enriching it with minerals, particles, ions, organic acids and other organic compounds, and microorganisms (Drever, 1997).

Water that infiltrates the soil can flow through different paths. Depending on soil and rock properties together with the volume of water that percolates in a certain amount of time, part of the water volume would occupy rock pores and may flow towards deeper rock layers by gravity (Ward et al., 2015). Part of the water would be retained in the soil and rock pores due to tension forces with the surface of the pores. The presence of plant roots or rock ruptures can create preferential paths for the water. The water can also reach a saturated or impermeable layer and then flow in parallel with the surface until it reaches the surface again due to slope changes creating springs (Gupta, 2011).

As per the above accounts, it is expected that by changing the land cover and using the land for different purposes will change certain properties that will affect water flows (e.g. Harden et al., 2013). Land conversion from forest to bare soil, for instance, can have strong effects on evapotranspiration patterns due to a sharp decrease in water uptake by plants and transpiration (Coe et al., 2013; Davidson et al., 2012). Removing plants from a certain area may also have implications on the erosive impact of water on the ground as the interception effect decreases and the water can hit the soil more directly (Araujo et al., 2005). The impacts of heavy rainfall on a bare soil is directly linked with soil decreased permeability and erosion (Renard et al., 1997). Deforestation also affect how the solar radiation reaches the surface as the absence of trees open more space for direct exposure of the ground to sunlight. This may have a microclimatological effect on the lower atmosphere humidity and air temperature and therefore, also on evapotranspiration patterns (Coe et al., 2013; Laurance and Williamson, 2001).

Several soil properties may change depending on the use of land after deforestation. Cattle ranching, for instance, may induce soil compaction by the pressure of the cattle trampling on the ground (Araujo et al., 2005; Ward et al., 2015). However, this process would certainly depend on the herd density in each case. The reduced amount of soil pores due to compaction may decrease its infiltration capacity leading to more runoff than otherwise. Poor agricultural practices can lead to an increase in erosion processes and in sedimentation loading on lowlands and water bodies. Increased turbidity caused by sediments may reduce the possibilities of water use for certain purposes (Bilotta and Brazier, 2008). Degraded soils and erosion also lead to higher losses of soil nutrients by runoff that would be previously used by plants (Pimentel et al., 1995). The loss of soil nutrients can lead not only to water quality problems due to high concentration of nutrients in rivers and lakes, but also to a decrease in agricultural productivity (Pimentel et al., 1995). To overcome problems of productivity, farmers would end up using more fertilizers that would be eventually washed from soil surface leading to higher nutrient concentrations in water bodies. Nutrient in excess can also percolate the soil column and contaminate groundwater (Oenema et al., 1998). Additional common problems found in intensively used lands for agriculture and cattle ranching are water contamination with pesticides and animal defecation (Bragina et al., 2017). When farmers allow their animals to ranch close to streams and springs, the animals may destroy the riparian vegetation and soil structure by stepping into it, and contaminate water by defecating making it inappropriate for human consumption (Bragina et al., 2017).

In order to tackle such complex problems, there is a need for institutional arrangements. We proceed by briefly reviewing a few of them in the context of the land-water links.

2.2 Institutional arrangements in the land-water context

Given the complexity portrayed so far, the land-water link management can be deeply complex when many individuals or groups share the same area and use the same resources (Niasse and Cherlet, 2014; Pahl-Wostl et al., 2012). As the water can flow long distances throughout a watershed, every action undertaken in upper lands may have consequences for the downstream water users (FAO, 2006). It is not just a matter of what upstream users do with the *water* itself that may interfere in the water available for those downstream but also what they do with the *land* as previously explained (Bragina et al., 2017; Coe et al., 2013; Harden et al., 2013).

Water flowing on rivers when used for consumptive purposes can be considered as a good characterized by high subtractability, i.e. the more is extracted from the river, the less remains to others to use it (Ostrom, 2005a). Non-consumptive uses of water does not imply subtractability, such as for tourism, however certain types of use can generate contamination which reduces the possibilities for others to use it. It is very hard to exclude or prevent users from accessing rivers because rivers usually flow across large areas. Therefore, taking into consideration consumptive uses, water from rivers can be called a *common pool resource* (Ostrom, 2005a).

The challenges to manage common pool resources, such as water, have led government authorities and technicians, civil associations, socio-environmental practitioners and researchers to propose several institutional arrangements in a variety of governance levels, e.g. integrated river basin management plans (FAO, 2006; Pahl-Wostl et al., 2012), riparian buffer width regulations (Lee et al., 2004), fees based on the polluter-pays principle (Howarth, 2009), etc.

Among the main challenges in these arrangements, there are the transaction costs. Due to inherent complexity, environmental policies may have high transaction costs of policy implementation, monitoring, and sanctioning (McCann, 2013; Thompson, 1999). Transaction costs can be understood as costs incurred in establishing, maintaining and changing institutions[3] and organizations (Marshall, 2013). McCann (2013) explores several factors that may affect transaction costs of environmental policies, such as number of agents (e.g. farmers in a watershed), scale of intervention, measurability, external effects, uncertainty, etc. High transactions costs may compromise the efficiency of a policy choice or even impede it to be fully implemented (Thompson, 1999).

[3] Institutions can be understood as: ""...the humanly devised constraints that structure political, economic and social interaction. They consist of both informal constraints (sanctions, taboos, customs, traditions, and codes of conduct), and formal rules (constitutions, laws, property rights) (North, 1991, p. 97)"

Claims of government *inefficiency* always make some voice for the proposition of different institutional arrangements. Partnerships between government and third sector have been one of these varieties since the 1980's (Salamon, 1987), and some examples can be found in the conservation sector (e.g. Moreno-Padilla, 2016). During the last decades, an increasing emphasis has been put on community-level approaches (e.g. Peters, 1998) managed by intermediary organizations, often NGOs or civil associations of different kinds, and market-based schemes for the management of natural resources (Pahl-Wostl et al., 2012).

Payments for ecosystem services (PES) are among the most advocated institutional arrangements for conservation on a community-level nowadays. The idea behind such schemes is that landowners living in areas from where others usually obtain ecosystem services, called ES "providers", should be paid by ES users to maintain or improve such ES by changing their land use or implementing some conservation practices (Wunder, 2005). These schemes can be classified in two types (Wunder, 2007): (a) *public schemes*, in the form of governmental programmes, and (b) *private schemes*, with a more local focus. In public schemes, the state represents the ES users and pays the landowners living in strategic areas for conservation to reduce the impact of their activities on the natural resources. In private schemes, an intermediary organization is usually in charge of setting the transactions between ES users and the so-called "providers". In what follows, we review the concepts of ES and its origins and explore the current PES practices with an emphasis on water-related cases (PWS schemes).

2.3 The Ecosystem Services paradigm and its origins

Ecosystem services (ES) is a widely used concept nowadays, and it could be understood as a new paradigm, not only in environmental sciences and ecology, but also in the science-policy-practices interface (Fisher and Brown, 2014; Kull et al., 2015). Its most cited definition is the one proposed in the Millenium Ecosystem Assessment - MA (2003, p. 49):

> "Ecosystem services are the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits;

> and supporting services, such as nutrient cycling, that maintain the conditions for life on Earth."

Another definition for ES, closely related, was previously proposed by Daily (1997, p. 3):

> "Ecosystem services are the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life. They maintain biodiversity and the production of ecosystem goods, such as seafood, forage, timber, biomass fuels, natural fibber, and many pharmaceuticals, industrial products, and their precursors. In addition to the production of goods, ecosystem services are the actual life-support functions, such as cleansing, recycling, and renewal, and they confer many intangible aesthetic and cultural benefits as well."

The MA report proposes a definition for *ecosystem*:

> "An ecosystem is a dynamic complex of plant, animal, and microorganism communities and the non-living environment, interacting as a functional unit. Humans are an integral part of ecosystems (Millenium Ecosystem Assessment, 2003, p. 49)."

Gómez-Baggethun et al. (2010) presented an overview of the history of ecosystem services from the perspective of the economic theory. Based on their timeline (p. 1213), this section unfolds some of the key events and publications that were directly related to the origins of the concept and to its widespread uptake by decision makers, academics, and conservation practitioners.

According to Mooney and Ehrlich (1997) the first known time that the idea of nature as a provider of services to society appeared was in Marsh's book "Man and Nature", 1864. Marsh noted, "The carnivorous, and often the herbivorous insects render an important service to man by consuming dead and decaying animal and vegetable matter..." (Marsh 1864, p. 95 *cited in* Mooney and Ehrlich 1997). Following a list of other references, Mooney and Ehrlich mentioned William Vogt (in 'A Road to Survival', 1948) as a pioneer of the related concept of 'natural capital': "By using up our real capital of natural resources, especially soil, we reduce the possibility of ever paying off the debt (Vogt 1948, p. 44 *cited in* (Mooney and Ehrlich, 1997)".

As for ‘ecosystem services’, several definitions followed until it gained a mainstream use: ‘environmental services’ (Study of Critical Environmental Problems, 1970); ‘public services of the global ecosystem’ (Ehrlich et al., 1977); ‘nature’s services’ (Westman, 1977); and finally ‘ecosystem services’ (Ehrlich and Ehrlich, 1981). A series of studies followed in the subsequent years focusing on the services provided by ecosystems and the role of biodiversity in the ecosystem’s structure.

Costanza and Daly (1992) explored the early notions of ‘natural capital’, a concept intimately related to that of ecosystem services. Natural capital was then defined as “the stock that yields sustainable flows” while the sustainable flows would be called ‘natural income’ (Costanza and Daly, 1992, p. 38). They argued that society could not afford decreasing their stock of natural capital given the uncertainty about the sustainability of this potential situation. This publication was one of the first to explore the idea of quantifying natural capital and helped promote the ecosystem services approach.

By 1996, ‘environmental services’ were already incorporated in the federal law of some countries; e.g. Costa Rica’s Federal Law n. 7575/1996 recognized four types of environmental services provided by forested areas, including carbon sequestration and hydrological services (Postel and Thompson, 2005).

In 1997, the book edited by Gretchen Daily, “Nature’s Services – Societal Dependence on Natural Ecosystems” was published. This book became one of the cornerstones of the history of the ecosystem services concept and one of the first ones to advocate clearly for an economic valuation of these services. In the same year, Costanza et al. (1997) published an influential paper on Nature in which they estimated the ecosystem services value of the entire biosphere to be 33 Trillion US Dollars per year on average. Their attempt to estimate this value in monetary units was followed by subsequent updates (e.g. de Groot et al., 2012).

In 1998 an international effort begun to develop the conceptual framework of the MA (Millenium Ecosystem Assessment, 2003, p. xiii). A number of development cooperation agencies, financial institutions, and scientific councils provided financial support to perform this large study. The main goal of the report published in 2003 was to provide an updated global assessment of the state of ecosystems around the world and their services.

In 2007, ministries of the G8+5 countries launched an initiative to study the economic benefits of biodiversity and ecosystems – The Potsdam Initiative. This process further established the "The Economics of Ecosystems and Biodiversity" (TEEB) with support from the United Nations Environmental Programme (UNEP) (European Communities, 2008). The central idea was to highlight the values of biodiversity and ecosystems and propose ways to incorporate a valuation framework into policy making (European Communities, 2008). The initiative launched further studies in the subsequent years.

In 2012, the Intergovernmental Science-policy Platform on Biodiversity and Ecosystem Services (IPBES) was launched bringing together initially 94 governments to improve scientific information to support policy processes about ecosystem services and biodiversity (Díaz et al., 2015). IPBES is supported by several United Nations bodies and is managed by the United Nations Environmental Programme (UNEP). In the same year, the Ecosystem Services journal was launched (Braat and de Groot, 2012).

In the following section the origins, definitions, practices and status of PES are reviewed.

2.4 Payments for Ecosystem Services

During the 1980's and 1990's one type of conservation approach became popular among practitioners and international donors aiming at investing on environmental projects in developing countries: the integrated conservation and development projects (ICDPs) (Newmark and Hough, 2000). The main idea was to reconcile biodiversity conservation and local development through a series of activities in protected areas and their surrounding inhabited zones (Peters, 1998; Wells et al., 1999). ICDPs proponents were concerned with reducing the socio-economic impact of protected areas by generating opportunities for sustainable resources use. According to Wells et al. (1999) the concept gained strength due to an emphasis on participation of local communities on design and implementation, the idea of combining concerns with conservation and poverty relief, and finally because it was attracting a large amount of international investments in biodiversity conservation.

However, after one or two decades of ICDP attempts, some researchers and development practitioners were pointing to a failure in several projects. Wells et al. (1999) published a World Bank report in which they reviewed 21 cases of ICDP projects in Indonesia and concluded that the majority of them were not achieving satisfactory results. According to them, the observed ineffectiveness was not actually related to the ICDP concept itself, but rather to lack of management capacity, poor law enforcement, and the influence of powerful actors outside the realm of protected areas. Peters (1998) presented the case of a national park in Madagascar in which the ICDP attempt was considered deficient. One of the points made was that a large amount of money supposedly intended for these projects were actually being diverted to U.S. based administrative overheads and technical consultants from abroad. Only 2% of the initial amount would reach the target population. Additional he calls "to redistribute money or other resources directly to the poor people living in and around the protected areas" and to focus on local education and organization (Peters, 1998, p. 17). By taking these arguments, some researchers, mainly economists, have strongly made the case for *direct payments for conservation* to replace such projects (Ferraro, 2001; Ferraro and Kiss, 2002; Ferraro and Simpson, 2002). According to Ferraro (2001):

> "Conservation contracting can (1) reduce the set of critical parameters that practitioners must affect to achieve conservation goals, (2) permit more precise targeting and more rapid adaptation over time, and (3) strengthen the links between individual well-being, individual actions, and habitat conservation, thus creating a local stake in ecosystem protection (Ferraro, 2001, p. 990)."

In sum, the arguments in favour of payments were centred on the idea that they would be more direct, simple, target-oriented, less costly, and therefore, more efficient. In a highly cited *opinion* paper that influenced conservation funding in the last 15 years, Ferraro and Kiss (2002, p. 1719) argue that:

> "The basic principle is that the cheapest way to get something you want is to pay for what you want (e.g., protected rain forest), rather than pay for something indirectly related to it (e.g., capital for improving eco-tourism), or more simply 'you get what you pay for.'"

Apparently, the authors assumed a very *narrow perspective over human behaviour* in their attempt to justify the advocacy made in favour of direct payments:

> "However, people will generally do what is in their own interest, particularly their short-term interest. If they can receive more benefits from clearing an area of habitat than they could from protecting it, they will clear it (Ferraro and Kiss, 2002, p. 1719)."

These arguments paved the way to popularize PES among development agencies, international foundations for conservation, and non-government organizations. A Payment for Ecosystem Services (PES) is an institution designed to reach conciliation of interests among individuals or groups whose activities may cause impact on the goods shared with or used by others (Muradian et al., 2010). As a previously mentioned example, in the case of a watershed, the use of land by some individuals in upper catchments may decrease the quality of the water that is used by others downstream. When the costs of monitoring and law enforcement are high, financial incentives may be used to convince land users to adopt certain practices that would guarantee that water users would not be impacted (Lu and He, 2014). Proponents of PES sustain that economic incentives or compensations in voluntary agreements that at least can cover the opportunity cost of land use can induce a change of behaviour that would favour reaching a fair deal for all stakeholders (Wunder, 2007).

While several scientific papers have been devoted to PES definitions and its implications (Derissen and Latacz-Lohmann, 2013; Muradian et al., 2010; Sommerville et al., 2009), for now the most cited definition up to date should be enough to understand its origins and context. Wunder (2005), p. 3) proposes that a *Payment for Environmental Service* would be:

(1) "a voluntary transaction in which…
(2) a well-defined environmental service (or a land use likely to secure that service)
(3) is 'bought' by a buyer
(4) from a provider
(5) only if the provider continuously secures the provision of the service."

Apparently, the U.S. has a long tradition on payments for land retirement by farmers. According to Claassen et al. (2008), since the 1930's several voluntary payment schemes were undertaken by the federal government for a variety of purposes. Although much intended to increase crop prices and to support farmers during the economic recessions, it was also applied to incentivize soil conservation practices motivated by episodes such as the dust bowl. The Agricultural Conservation Program (ACP) established in 1936 supported farmers on the implementation of several soil conservation structures, and from 1996 onwards integrated also requirements from the Environmental Quality Incentives Program (Claassen et al., 2008). According to Ferraro and Kiss (2002), during the year 2001 around 1.7 billion dollars were spent by the U.S. government in incentives for farmers to protect land. Not only goverments were engaging in direct incentives but also large non-government organizations (NGOs). By the end of the 1990's not only governments and development agencies but also international NGOs, such as World Wildlife Foundation (WWF), Conservation International (CI) and The Nature Conservancy (TNC), were already investing largely in direct incentives for conservation (Ferraro and Kiss, 2002).

In Europe, the so-called agri-environment measures started to be implemented in the early 1980's by some of the European Union member States, it was adopted in a voluntary basis by the European Community in 1985 and formally introduced in the Common Agricultural Policy (CAP) reform in 1992 (European Commission, 2005). The introduction of agri-environment measures was a consequence of growing environmental concerns and complemented a series of actions to assist farmers on landscape conservation and sustainable agricultural production, with practices such as reduced use of fertilizers and maintenance of forest cover. Farmers would be stimulated to adopt conservation practices through direct aid payments:

> "Agri-environment measures are designed to encourage farmers to protect and enhance the environment on their farmland. It provides for payments to farmers in return for a service – that of carrying out agri-environmental commitments that involve more than the application of usual good farming practice. Farmers sign a contract with the administration and are paid for the additional cost of implementing such commitments and for any losses of income (e.g. due to reduced production) which the commitments entail (European Commission, 2005, p. 3)."

PES programs reached the policy agenda in Latin America in the early 1990's. The most iconic one was the Costa Rica national PES programme in 1997 aiming at protecting the forests based on the argument of provision of several environmental services (Pagiola, 2008). The payments were funded through a National Forestry Fund (FONAFIFO) that was fed by taxes on fossil fuels and loans and grants from The World Bank and Global Environmental Facility (GEF) (Postel and Thompson, 2005). This national program was based on a 1996 federal law (Law n. 7575) that recognized four types of environmental services provided by forests, one of them being the hydrological services (Postel and Thompson, 2005). According to Pagiola (2008), similar efforts for forest conservation in Costa Rica started earlier than the national program with a series of incentive program attempts, e.g. the Forest Protection Certificate in 1995 that supported the replacement of timber production by forest protection. In these projects, land users receive an economic incentive to change their activity for a more sustainable one or to conserve remnant vegetation in their farms.

A classic case frequently reported in the literature is that of Quito, Ecuador, with a trust fund for watershed conservation proposed in 1996 and established in 2000, called FONAG (Postel and Thompson, 2005). This was the first of a series of what has been named *water funds*, a conservation scheme promoted by the NGO The Nature Conservancy (Calvache et al., 2012). The implementation of FONAG received support from US Agency for International Development (USAID), among other organizations. Frequently mentioned cases are those from Vittel and the New York City (NYC). The Perrier Vittel Company (France), sold to Nestlé Inc. in 1992 established a conservation project with local communities in 1993. The company pay farmers directly in order to protect the springs that are sources for its bottled water (Perrot-Maître, 2006). In the beginning of the 1990's, the New York City adopted a similar approach for upper catchment protection (Smith and Porter, 2010).

Several types of "services" have been considered in PES projects: atmospheric carbon removal, water resources protection, biodiversity, scenic beauty, etc. (Wunder, 2005). The number of schemes reported in the literature has been increasing. Grima et al., (2016) reviewed 40 cases of PES in Latin America. In their analysis, 50% were cases related to water resources, 28% included several services, 12% were related to landscape, 8% to carbon, and 2% to biodiversity. In a paper aiming at a global meta-analysis of PES patterns, Ezzine-De-Blas et al. (2016)

identified 584 records of PES schemes in an online database research from which they analysed 55. Their results showed that public sector PES schemes are in large number in Europe and Asia, while Latin America would have a diversified set of schemes.

In what follows, a review of the recent trends towards impact evaluation is presented and its influence on conservation projects is briefly discussed. The quest for impact evidence is then linked to the efforts being done to demonstrate additionality of PES schemes.

2.5 Impact Evaluation and its influence in conservation projects

The efficient use of funds destined to solve collective problems has always been a key issue in policymaking and is of concern for governments, development agencies, and NGOs alike (Gertler et al., 2011). Programmes and projects should not only be *effective*, but also *efficient*. While the concept of effectiveness has been associated with achieving the desired aims, the concept of efficiency goes further and refers to the relation between investments and outcomes (Mandl et al., 2008). Since the 1980's, best practices for efficient policies have been associated with a growing trend towards what has been called "evidence-based policy making"[4] (Mceldowney, 1997; Sanderson, 2002).

> "Evidence-based policy-making represents a contemporary effort to reform or re-structure policy processes in order to prioritize evidentiary or data-based decision-making. Like earlier efforts in the 'policy analysis movement,' its aim is to avoid or minimize policy failures caused by a mismatch between government expectations and actual, on-the-ground conditions through the provision of greater amounts of policy-relevant information (Howlett, 2009, p. 153)."

Evidence-based policy-making became strong in the UK public health sector in the early 1990's and from there it was promoted towards other spheres, such as in education and criminology (Hammersley, 2005; Sanderson, 2002). This trend promoted certain types of research methods, such as *systematic reviews*, in detriment of others (Gertler et al., 2011), and of scientific knowledge in detriment of 'non-scientific' knowledge (Hammersley, 2005). The

[4] According to the Oxford English Dictionary, *evidence* means "the available body of facts or information indicating whether a belief or proposition is true or valid (Oxford University Press, 2017)."

evidence-based policy making trend also strengthened the use of performance indicators, experimental and quasi-experimental research designs in both governmental and non-governmental spheres.

The World Bank has been promoting evidence-based policymaking in the form of training workshops to government officials in many countries (Gertler et al., 2011):

> "Our hope is that if governments and development practitioners can make policy decisions based on evidence – including evidence generated through impact evaluation – development resources will be spent more effectively to reduce poverty and improve people's lives (Gertler et al., 2011, p. xii)."

As part of this effort towards effective or even efficient policy decisions, *Impact Evaluations* (IE) became one of the central tools:

> "Impact evaluations are part of a broader agenda of evidence-based policy making. This growing global trend is marked by a shift in focus from inputs to outcomes and results. From the Millennium Development Goals to pay-for-performance incentives for public service providers, this global trend is reshaping how public policies are being carried out. Not only is the focus on results being used to set and track national and international targets, but results are increasingly being used by, and required of, program managers to enhance accountability, inform budget allocations, and guide policy decisions. Monitoring and evaluation are at the heart of evidence-based policy making (Gertler et al., 2011, p.2)."

Impact evaluation focuses on *attribution*, i.e. it seeks to verify if the changes observed in a target group are attributable to the program or project being evaluated or to confounding factors (Baylis et al., 2015; Ferraro, 2009; Gertler et al., 2011). A key element of Impact Evaluation is *Additionality*. Assessing additionality means comparing interventions' effects with the null hypothesis or counterfactual (Baylis et al., 2015; Georghiou, 2002). A counterfactual, in this case, refers to what would have happened in the absence of the intervention that is being evaluated. Usually, it requires a comparison with a case control, being it an area without the project intervention or a group of individuals without the project *treatment* (Gertler et al., 2011). The logic follows that of a lab experiment: with treatment, without treatment, while all other conditions are kept constant for both. In sum, "the essence of counterfactual thinking is elimination of plausible rival interpretations of observed outcomes (Ferraro, 2009)."

Initial conditions of both groups (treatment and control) are represented in terms of a *baseline* for each variable of interest (Figure 2-1). Therefore, a baseline refers to the situation before treatment. At the same time, monitoring is used to observe and register the changes that those variables will suffer along the time. Monitoring is also important to verify if the project is actually achieving the goals by comparing observed variables with the established targets.

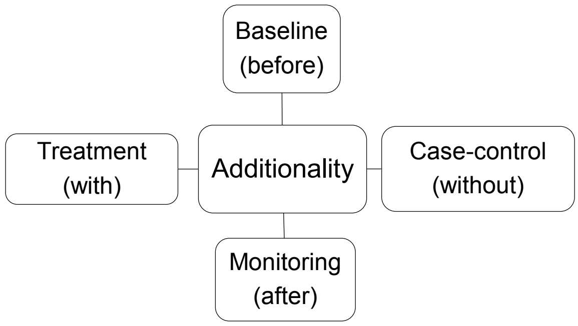

Figure 2-1: four elements of additionality assessment. Baselines to describe initial conditions; Monitoring to track changes along the intervention; Case-control and a Treatment case under similar conditions.

This increasing trend towards evidence-based policymaking has been putting a strong emphasis on the integration of science in the policy process. While imposing new challenges to those who are in charge of producing the *evidence*, it also gives room to critical questions about what would constitute evidence and what types of methods should count as appropriate to generate evidence (Hammersley, 2005):

> "The ideal model of evidence-based policy making is predicated upon certain assumptions relating to: the nature of knowledge and evidence; the way in which social systems and policies work; the ways in which evaluation can provide the evidence needed; the basis upon which we can identify successful or good practice; and the ways in which evaluation evidence is applied in improving policy and practice (Sanderson, 2002, p. 5)."

Recently, voices from the conservation research community pointed to the need to incorporate such evidence-based policy in the environmental agenda (Baylis et al., 2015; Ferraro, 2009). It is said that the environmental conservation science and policy are far behind several other fields such as public health and education (Baylis et al., 2015; Ferraro, 2009). Promoters of impact evaluation argue that this evidence-based approach would help to achieve more cost-effective conservation and support assessment across several projects. However, there are considerable barriers in producing evidence of conservation projects impacts. These hindrances are related to a number of factors: lack of evaluation culture among conservation practitioners, institutional conditions, funding scarcity, scale issues, and the high complexity of the ecological processes (Baylis et al., 2015; Ferraro, 2009).

Despite the difficulties of implementing impact evaluation in conservation projects, PES advocates incorporated it in their ideal conceptualization of a PES scheme. The *additionality* has been expressed in the literature as a pre-condition for PES schemes to be considered effective (Boerner et al., 2017; Wunder, 2005) and now several researchers are dedicated to the task of assessing effectiveness based on impact evaluations (e.g. Martin et al., 2014). In the context of the mainstream definition of PES (Wunder, 2005), more science would be needed to demonstrate 'service delivery' and the *additional* effects of such projects. While economists set up the rules of what should be considered effective and what should count as evidence, environmental practitioners dig desperately into monitoring techniques and field control conditions to satisfy these demands. Whenever the evidence of effectiveness is not found, the problem is not thought to be the *framing* itself but rather the lack of *proper* science; therefore, more science should be pursued to support this quest (see Naeem et al., 2015). The strong emphasis that is put on scientific methods for impact evaluation that would rather resemble laboratory conditions than the real environment is clearly shaped by a positivist mentality (Sanderson, 2002). The evidence is taken for granted; it is just a matter of doing proper science. It seems to have a blind faith in the scientific process disregarding subjective aspects of the knowledge production (Barker and Kitcher, 2014). However, scientific uncertainty is always present and can challenge such approaches.

In order to understand the influence of uncertainty on impact evidence applied to conservation projects, such as PES, some basic concepts about ignorance and uncertainty are presented in the following section. Further details are presented in Chapter 3.

2.6 Ignorance and Uncertainty

Ignorance is popularly understood as "something in need of correction, a kind of natural absence or void where knowledge has not yet spread" (Proctor and Schiebinger, 2008, p. 2). At a more subjective level, ignorance has always been an object of reflexion even among the ancient Greek philosophers (*"I know that I know nothing"* – attributed to Socrates), and in a more instrumental error calculation has been a regular scientific practice since centuries ago (Stigler, 1990). However, concerns about the impact of uncertainty in policy decisions increased exponentially with the emergence of debates about technological and environmental risks in the last decades (Funtowicz and Ravetz, 1990a). In addition to technical approaches such as risk assessments emerging from quantitative disciplines, sociology and philosophy have been also increasingly interested in the study of what is *not known* and its impacts in society (Gross, 2010). Even a new name to aggregate the studies about *ignorance* has been recently proposed: *agnotology* (Proctor and Schiebinger, 2008).

Discussions about *nonknowledge* or *ignorance* frequently end up in a paradox:

> "... whenever new knowledge arises, the amount of nonknowledge that is perceived can increase proportionally since every set of newly generated knowledge can open up a wider horizon of what is not known (Gross, 2010, p. 52)."

The paradox of increasing ignorance by increasing knowledge leads us to assume that nothing can be ever completely known. This idea matches the definition of *uncertainty* given by (Walker et al., 2003, p. 5): uncertainty is "any deviation from the unachievable ideal of completely deterministic knowledge of the relevant system." Uncertainty is, therefore, an intrinsic aspect of knowledge and may grow with it:

> "New knowledge on complex processes may reveal the presence of uncertainties that were previously unknown or were understated. In this way, more knowledge

illuminates that our understanding is more limited or that the processes are more complex than thought before (Walker et al., 2003, p. 8).”

Several authors came to understand uncertainty in very different terms and there is no unique definition or frameworks for its study (Beven, 2009; Brown, 2010; Gross, 2010; Morgan and Henrion, 1990; Walker et al., 2003). Some scholars tend to concentrate on technical aspects of uncertainty, in the context of policy analysis of risk (Morgan and Henrion, 1990; Walker et al., 2003), or modelling exercises (e.g. Beven, 2009). Others look at uncertainty as a more holistic concept in the process of knowledge production (e.g. Gross, 2010). Still, what seems to be a unanimous opinion among scholars is that uncertainty has different sources, dimensions and magnitudes (Walker et al., 2003).

Gross (2010, p. 68) made an extensive review of concepts related to ignorance and their definitions in the literature. He proposes the following terminology (Table 2-1):

Table 2-1: “Categorization of different unknowns and extended knowledge” (Gross 2010, p. 68).

Nescience	Lack of any knowledge: a prerequisite for a total surprise beyond any type of anticipation; can lead to ignorance and nonknowledge but belongs to a different epistemic class.
Ignorance	Knowledge about the limits of knowing in a certain area: Increases with every state of new knowledge.
Types of specified ignorance	
Nonknowledge	Knowledge about what is not known but taking it into account for future planning.
Negative Knowledge	Knowledge about what is not known but considered unimportant or even dangerous; can lead to nonknowledge (related to undone science).
Extended knowledge	Alternatively, new knowledge: based on planning and/or research with nonknowledge; can lead to new ignorance by uncovering limits of the newly gained knowledge.

This section is complemented by the conceptual analysis presented in the Chapter 3 concerning the sources and types of uncertainty in PES. In the following paragraphs, we proceed by reviewing some attitudes towards uncertainty in the science-policy interface in order to provide a background to subsequent chapters and to explore to which extent scientific methods can support claims of effectiveness in conservation projects, such as PES.

2.7 Attitudes and approaches towards uncertainty

Uncertainty, as an inherent feature of research, is not a problem *per se*, but becomes particularly problematic when decisions need to be taken, as in the case of pressing policy issues regarding technological risk, public health, etc.:

> "The point is that scientific knowledge proceeds by exogenizing some significant uncertainties, which this become invisible to it: as Kuhn noted, this is not a pathology of science but a necessary feature of structured investigation. The built-in ignorance of science towards its own limiting commitments and assumptions is a problem only when external commitments are built on it as if such intrinsic limitations did not exist (Wynne, 1992, p. 115)."

Therefore, the perceptions and attitudes of actors in charge of taking collective decisions towards scientific uncertainty become important. Some scientists tend to assume that uncertainty should not *simply* be presented to decision makers when they ask for scientific advice (e.g. Todini and Mantovan, 2007). Others believe that an open debate about uncertainties and the ways to cope with them are the best approach (e.g. Brown, 2010; Walker et al., 2003). In an interesting debate about this issue, hydrologists pointed their own concerns about uncertainty and the use of scientific products by practitioners and other stakeholders (Beven, 2008, 2006; Hall et al., 2007; Hamilton, 2007; Sivakumar, 2008; Todini and Mantovan, 2007). Beven (2006) was criticized in conferences because of his emphasis on model uncertainty and the risk of undermining the confidence of model users and stakeholders on science. Among other points made, Todini and Mantovan (2007) argued that decision-makers in use of hydrological forecasts were still not prepared to properly benefit from the information derived from uncertainty analysis and utility functions should rather be preferred instead of plain uncertainty numbers. Beven (2006) argued that the assumption that stakeholders are not ready to deal with uncertainty in decision-making processes is outdated as decision-makers deal with uncertainty on a daily basis. Hall et al. (2007, p. 985) supported this perspective by saying that "decision-makers and members of the public have a greater capacity to cope with probabilistic information than is often assumed". The heated debate also unveiled concerns about poor scientific practices and a call for transparency for the sake of the young generations of hydrologists:

> “... gradually I have come to the realization that I have a history of parameter-abuse. (...) The signs of addiction are subtle but recognizable. Hydrographs that are just a little too good, where the uncertainty in model predictions is less than the uncertainty in the driving force data. Axis-scaling that is a little too compressed, hiding inconsistencies in the model fit. You may recognize these symptoms in your colleagues but deny that you too... (Hamilton, 2007, p. 1979)”

Many researchers assume that decision-makers on policy debates are not interested in knowing about scientific uncertainty, but would rather prefer scientists to come up with straight numbers. As Walker et al. (2003, p. 6) put it, “It is widely held that policymakers expect scientists to provide certainties and hence dislike uncertainty in the scientific knowledge base.” One example of this perception is given by Todini and Mantovan (2007, p. 1634):

> “End-users and stakeholders are NOT interested at looking at the uncertainty bounds. They are interested in receiving scientific support to corroborate their decisions, which may have dramatic consequences.”

In his study about the use of science at the U.S. Environmental Protection Agency, Powell (1999, p. 148) made a similar claim: “...more often than not, policymakers are disappointed because they want definitive answers from uncertain science and they cannot avoid making value-laden policy judgments.”

The need for scientific inputs on the decision-making processes combined with this complex interaction between those in charge of “producing science” and those in charge of using scientific information have led to the predominance of certain approaches to uncertainty and risk. Quite often, quantitative methods aiming at “reducing uncertainty” or focusing only on those types of uncertainty that can be quantified are preferred (Brown, 2010; Wynne, 1992). One such type frequently mentioned by critical researchers on uncertainty is the *risk assessment* methods:

> "Here is relevant simply to note that conventional risk assessment methods tend to treat all uncertainty as if they were due to incomplete definition of an essentially determinate cause-effect system. In other words, they suggest that the route to better control of risks is more intense scientific knowledge of that system, to narrow the supposed uncertainties and gain more precise definition of it (Wynne 1992, p. 116)."

There are certainly several reasons for the prevalence of quantitative and reductionist methods to assess uncertainty. Psychologically, such methods may be preferred because they support a sense of control and predictability over risky situations (Brown, 2010). Critical perspectives on philosophy of science also consider that this is a consequence of the predominance of natural sciences approach in science in detriment of other ways of inquiry (Barker and Kitcher, 2014). According to Barker and Kitcher (2014), the emphasis on reductionist strategies is guided by a quest towards objectivity and universality. Under this perspective, any property that cannot be measured based on a known unit cannot be entirely defined and therefore is subjective and not objective. By analysing objects focusing on measurable properties and disaggregating it in its component parts, scientists aim at reaching universality by looking at mathematical patterns that could be defined and replicated in other contexts (Barker and Kitcher, 2014).

Barker and Kitcher (2014) propose an answer to why such approaches are so attractive. Science has been increasingly demanded and paid by governments, companies, development agencies, financial institutions. These different social actors have their own agenda and are seeking to fulfil certain interests and demands that are somehow always associated with intervention and control over processes in the world. Numbers, associated with a sense of predictability and control, allow them to provide accountability reports to their peers or shareholders, justify public expenditure, show results to their voters, and provide useful and tractable information to obtain or provide funds.

> "Expert advice is often thought most useful to policy when it is presented as a single 'definitive' interpretation. Even when experts acknowledge uncertainty, they tend to do so in ways that reduce unknowns to measurable 'risk'. In this way, policy-makers are encouraged to pursue (and claim) 'science-based' decisions (Stirling, 2010, p. 1029)."

An additional reason for the preference for quantitative approaches has deep implications: numbers are more easily understood and managed by economists and those who take decisions regarding fund allocation. Because monetary value is also expressed in numbers, there is a supposedly easy association of economic approaches with whatever other numeric ones. To add to this, Funtowicz and Ravetz (1994) brilliantly expressed: “Economics has traditionally been able to maintain its credibility by relegating uncertainties in knowledge and complexities in ethics firmly to the side-lines.” Maybe for the same reason, the ecosystem service approach gained so much prominence now that monetary values can be artificially attached to measurable natural processes (now *services*) and materials (now *goods*) (see arguments from Robertson, 2012).

Risk assessments, although widely adopted to deal with complex problems such as environmental ones, were developed to deal with well-designed mechanical structures under highly controllable circumstances which is definitely not the case of environmental systems (Wynne, 1992). Efforts to reach precision, control and predictability through risk assessments in complex circumstances are certainly in great mismatch with the complexity not only of natural processes but also of social ones:

> “Risk assessment invites precision and even quantification, but by its nature is imperfect. Given the mobile character of modern institutions, coupled to the mutable and frequently controversial nature of abstract systems, most forms of risk assessment, in fact, contain numerous imponderables (Giddens 1991, p. 4).”

Luckily, philosophers and social scientists have been shedding light on those debates with contributions in the fields of philosophy of science, sociology of science, and science and technology studies (e.g. Barker and Kitcher, 2014; Beck and Bonss, 2015; Funtowicz and Ravetz, 1990; Giddens, 1991; Gross, 2010; Velody, 1995). An interesting statement is given by (Funtowicz and Ravetz, 1990):

> “Previously it was assumed that Science provided ‘hard facts’ in numerical form, in contrast to the ‘soft’, interest-driven, value-laden determinants of politics. Now, policy-makers increasingly need to make ‘hard’ decisions, choosing between conflicting

options, using scientific information that is irremediably 'soft' (Funtowicz and Ravetz, 1990, p. 1)."

A more than welcome example to illustrate this issue is a study by Stirling (2010, 2008) in which he compares a series of studies that aimed at providing measures of risk of adopting certain energy sources. The idea was to support policy-makers in taking decisions about energy options. He showed that although the individual and independent scientific studies provided very narrow ranges of uncertainty, there was absolutely no consensus when taken altogether (Figure 2-2). Therefore, any random sample of these studies could support very different ranking of energy technology options:

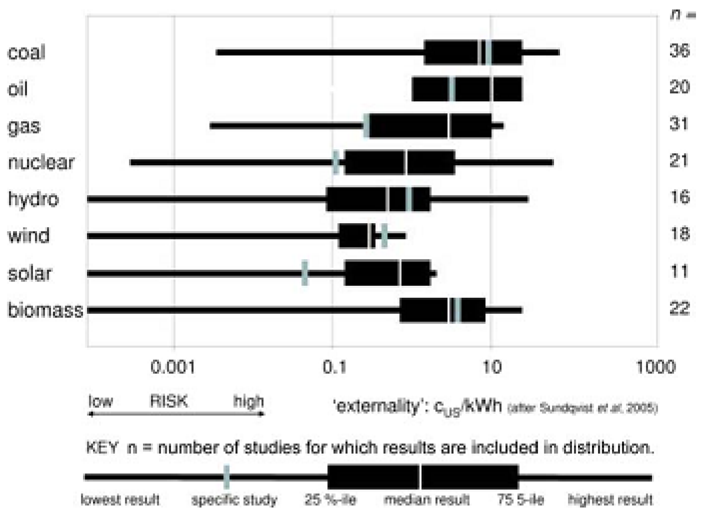

Figure 2-2: "the perils of science-based advice." Economic risk of energy technology based on an assemblage of studies showing no consensus among scientists. Source: (Stirling, 2008, p. 101)

Importantly, among natural scientists and economists wanting to reach definite numbers and reduce uncertainty to manageable risk (and attribute utility functions and monetary values wherever possible) there are some critical voices. These voices raise attention to alternative ways of seeing and interpreting the world and to other forms of quantitative and qualitative inquiry. For example, although Morgan and Henrion (1990) presents a whole book on quantitative methods to support policy analysis, they explicitly recognize that these methods are only supportive but not definitive and this is due to a large amount of uncertainty sources that cannot be treated by quantitative methods. Gross (2010) studied ecological restoration projects and explored how scientists and practitioners have been coping with uncertainty and surprise in such projects. He pointed to the importance of surprises in the learning process and offered some perspective on adaptive and transdisciplinary approaches. Stirling (2010, 2008), based on many years of scientific advisory work, proposed a very transparent treatment of uncertainty by confronting the scientific advice and its ambiguities inside the scientific community. He wanted to offer an overview of potential approaches to uncertainty that policy makers could use when choosing paths regarding new regulations involving risk and for that elaborated what he called the “uncertainty matrix” (Stirling, 2010, 2008).

According to Stirling (2010, p. 1029), most scientists in the position of giving advice to policy makers when confronted with uncertainty would avoid expressing broad doubts and acknowledging *unknowns* and would rather reduce uncertainty to measurable risk. Thus, alternative methods are usually neglected by policy-makers because they do not provide *round* numbers and conduce to definitive solutions. By supporting risk measurement approaches, policy makers would tend to claim that their decisions are “science-based”. However, in neglecting sources of uncertainty that cannot be quantified, decision-makers may be engaging in even more uncertain pathways. As pointed by Stirling (2010, p. 1030), “the absence of evidence of harm is not the same as evidence of absence of harm.”

"Frequently in public discussion, policy analysis, regulatory decision making and other contexts, we proceed as if we understand and can predict the world precisely. While a moment's reflection is sufficient to persuade anyone that this is not true, a number of political, behavioural, and analytical factors combine to promote the continuation of this practice." - Morgan and Henrion, 1990, p. 1

2.8 Evidence, uncertainty, and PES

The scientific and technological achievements of the last three to four centuries have supported increased expectations about what science can offer. Science has been seen by many as the most reliable way of accumulating knowledge (Barker and Kitcher, 2014). This based on the supposed reliability of the so-called "scientific method" (Velody, 1995). The scientific method, according to a perspective influenced by the work of prominent scientists such as Galileo, Bacon, Newton, Boyle, and Descartes, is centred in systematic observations that would be then generalized to reach conclusions (Barker and Kitcher, 2014; Velody, 1995). Hypotheses should only be accepted if supported by proper evidence. Although a large literature on critical perspectives over science and its limitations exists (e.g. Barker and Kitcher, 2014; Kuhn, 1970; Latour, 1987; Velody, 1995), there are still influential discourses that support the idea that "science-based" decisions are more trustworthy, and that policy decisions should be based on *evidence* (Funtowicz and Ravetz, 1990b; Hammersley, 2005; Sanderson, 2002).

Evidence, as a basis for science, refers only to what has been somehow observed. However, *observation*, as the ground for evidence, does not exist without the *observer*. It is therefore important to question what the features from the observer are that could affect the observation. In their search for evidence, scientists do not start from scratch but observe things from a reference point (Velody, 1995). This reference point include a series of pre-conditions: cultural origins of the scientist, gender, age, neurological and psychological structure and health, beliefs, moral values, preferred theories, and so on (Barker and Kitcher, 2014). In addition, the scientific process is embedded in a whole universe of social interactions and demands where influence, competition, individual interests, institutional arrangements, collaboration, power and conflicts all co-exist (Brown, 2010). Nowadays, one may also ask what the influence of the funding sources on the scientific production would be (Barker and Kitcher, 2014). The researcher depends on funds coming from companies, governments, development agencies, and so on, and therefore, she/he must somehow respond to the interests of those who pay for science. As Velody (1995, p. xii) put it, “once the majority of science is paid for by companies, by governments and by the military, it becomes far less easy to see science as disinterested.”

One may say that there is no neutral product in science. The qualities of the *observer*, the means and tools to *observe*, and even the researcher’s social circumstances influence the *observation* process. It is expected that all of these conditions will *frame the observation*, including in aspects such as scope, sample, goal, justification, hypothesis, research question, etc. Whenever a scientist draws the boundaries of the observed object, this is “detached” from the universe of possible sets of conditions and objects to observe. The scientist consciously (or not) ignores the rest and by doing so is able to handle certain objects to study (Brown, 2010). According to Brown, time, financial resources, technical assistance, available instruments, expertise..., all of these also constrain the set of potential observations, and therefore, the evidence that can be gathered.

On the light of these arguments, and the recent efforts to demonstrate additionality and conditionality of PES schemes, one could question how far scientific methods can actually go on supporting this quest and how feasible it is to proceed under such perspective. What has been pointed by many critics of ES and PES is that there is an uncountable number of uncertainties of various kinds, some of them linked to technical issues, others to lack of knowledge about the environment and its processes, and others created by the narrow *framing* (i.e., one based on monetary payments) of human-environment relationship (Barnaud and Antona, 2014; Kull et al., 2015; Lele, 2009; Norgaard, 2010; Robertson, 2012).

The next chapter of this dissertation explores the sources and types of uncertainty in PES schemes, including a discussion of technical aspects as well as concerns about the lack of knowledge the uncertainties that are inherent to the production of knowledge *per se*. Propositions about an adaptive approach to PES are presented.

3 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.

3.1 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 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; 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. 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 & 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 section 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.

3.2 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 & 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.

3.3 Limits of Knowledge

3.3.1 PES step-by-step and perceptual models

A *typical* PES scheme would be implemented in five major steps usually performed linearly (Fig. 1): (1) Proposition; (2) Studies; (3) Design; (4) Execution; and (5) Monitoring (Calvache et al., 2012; Engel et al., 2008; Ruiz-Agudelo et al., 2013; Salzman, 2009; Wunder, 2005). Negotiation, Evaluation and Reporting would go alongside steps (1) to (5) and support adjustments needed along the way, although frequently in a limited form.

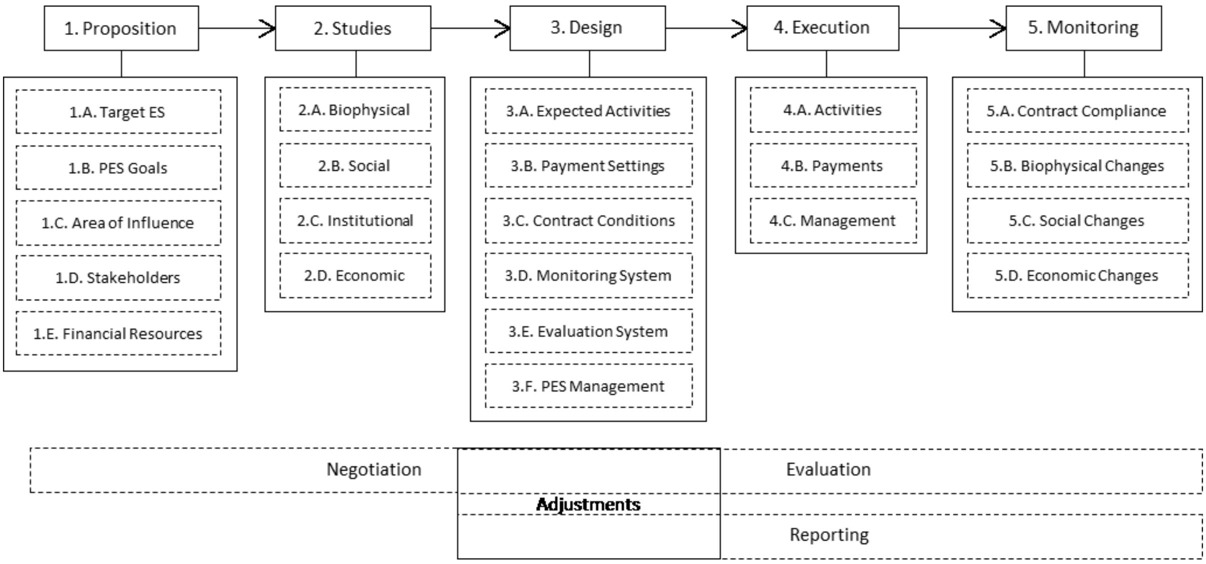

Figure 3-1: Steps and components of implementing a typical PES scheme performed linearly with limited feedback through evaluation and adjustments. Source: elaborated by the authors.

The proposition of a PES scheme (Figure 3-1, item 1) frames an environmental issue together with the causes of that issue. Hence, from the beginning, there is an idea of the HES in question and how it works, a "perceptual model" in the terminology of Beven (2009) or a "mental model" as referred to by Ostrom (2005) and others. Proposing a PES scheme also indicates that a specific problem-solving mindset is present, since other solutions for the same environmental issue could have been proposed instead. The studies conducted to characterize the system in question (Figure 3-1, item 2) are conditioned by this perceptual model, which dictates how and with what focus the system should be studied (Brown, 2010). The conservation activities proposed for the PES scheme (Figure 3-1, item 3.A) then are equally based on assumptions about how the system will behave under new conditions. In sum, the way we understand and conceive the HES, i.e. our perceptual model, shapes the way we "see" environmental issues and conduct decisions to solve them (Bardwell, 1991).

Our perceptual model is the product of a particular cultural, political and economic context, including the prevalent knowledge about the HES in question or, vice versa, what is not known (Krueger et al., 2016; Ostrom, 2005). Hence, some reflection upon the uncertainties of the HES will be helpful (not expecting that all of the following questions can be answered directly):

(a) What do we know? – referring to the current state of knowledge about the system

(b) What do we not know? –referring to lack of knowledge, unknowns, and scientific knowledge gaps; if we can answer this question, then we are in the domain of perceived non-knowledge or, as expressed by Gross (2010, p. 9), "acknowledgment of ignorance"

(c) What do we think we do not need to know? – asking if we consciously leave a knowledge gap, called "negative knowledge" by Gross (2010)

(d) What can be known? – referring to the perceived potential to know and the limits of knowledge

(e) How much time, effort and resources does something require to be known? – referring to the practical feasibility of coming to know

(f) What do we not know that we do not know? – referring to what Gross (2010) calls "nescience", unawareness of unknowns, a pre-condition for total surprise

The process of learning that is behind any decision-making process, therefore, ideally extends in several directions: towards surprises; towards perceived non-knowledge; and towards reviewing current knowledge to check for errors not detected previously. We learn when surprises turn nescience into new knowledge and perceived non-knowledge (Gross 2010). We look at past experiences and take lessons from our previous unawareness. While using current knowledge we can also face situations in which what was consciously left unknown (negative knowledge) turns out to be an important part to be taken into account in the future. The limits of knowledge that bound the way we perceive HES are a major source of uncertainty in PES schemes.

3.3.2 Scientific knowledge gaps

Arguably, assumptions connecting conservation practices and desired outcomes in PES schemes should be in accordance with available scientific knowledge (Palmer and Filoso, 2009). However, current scientific knowledge gaps may prevent some assumptions from being validated. Palmer & Filoso (2009, p. 575) argued that the "flurry of interest in ecosystem markets supplied by restoration" are "out of step with the science and practice of ecological restoration". In practice, many PES schemes have been implemented without clear causal relationships between land use practices and ES (Barnaud and Antona, 2014; Kosoy et al., 2007; Lele, 2009; Muradian et al., 2010). Instead, proxies such as "total forest area under protection" or "number of trees planted" have been used by practitioners to provide some evidence of environmental benefits (Ponette-González et al., 2014; Porras et al., 2008; Quintero et al., 2009; Wunder, 2005). For instance, it is common to see conservation projects based on the assumption that "a tree-dominated land cover will provide similar hydrologic services regardless of its structural or ecological properties" (Ponette-González et al. 2014, p. 4). Hydrological service provision, however, will depend critically on the hydrological properties of the system such as the extent of surface vs. groundwater catchment, hydrogeology, soil properties, geomorphology, microclimatology, etc. As Kosoy et al., 2007; Tallis et al., 2008; and Wunder, 2007 noted, the lack of demonstrable foundations made many PES schemes – especially water-related ones – based more on "faith" than on empirical knowledge.

Kosoy et al. (2007) compared common perceptions among PES payers regarding the links between land cover and hydrological services with the correspondent scientific positions. They found a frequent mismatch in the evaluations of forest cover effects on water quantity and regulation (when it came to the role of forest cover in water quality the payer and scientist positions where more aligned). Beyond this mismatch between public and scientific understanding, the science itself is far from settled. For instance, Lele (2009) emphasized the knowledge gaps regarding the forest-soil-water link and the related misconceptions behind ES related schemes, like PES. The author referred to lasting controversies in Hydrology regarding the effects of land use change on river discharge, floods, dry seasons, erosion, and sedimentation as discussed by Bruijnzeel (2004) and Calder (2004). As summarized by Montanari et al. (2009, p.1), "Hydrology is a science that is highly uncertain. The main reason for this uncertainty is that we still do not know the intrinsic dynamics of many hydrological and water quality processes".

Under-researched components and processes, controversies over concepts, and clashing frameworks may interfere with the contributions science can make to support PES schemes and hence must be taken into account. However, not only knowledge gaps as such are potential sources of uncertainty, but also the practice of *knowledge production* itself.

3.3.3 Knowledge production underpinning PES and uncertainty sources

Because there is an increasing trend towards supposedly "science-based" projects and policies, like PES schemes, it is of extreme importance to consider the constraints of scientific methods and the sources of uncertainty inherent in the knowledge production process, e.g. in modelling, measurement and data analysis (Figure 3-2).

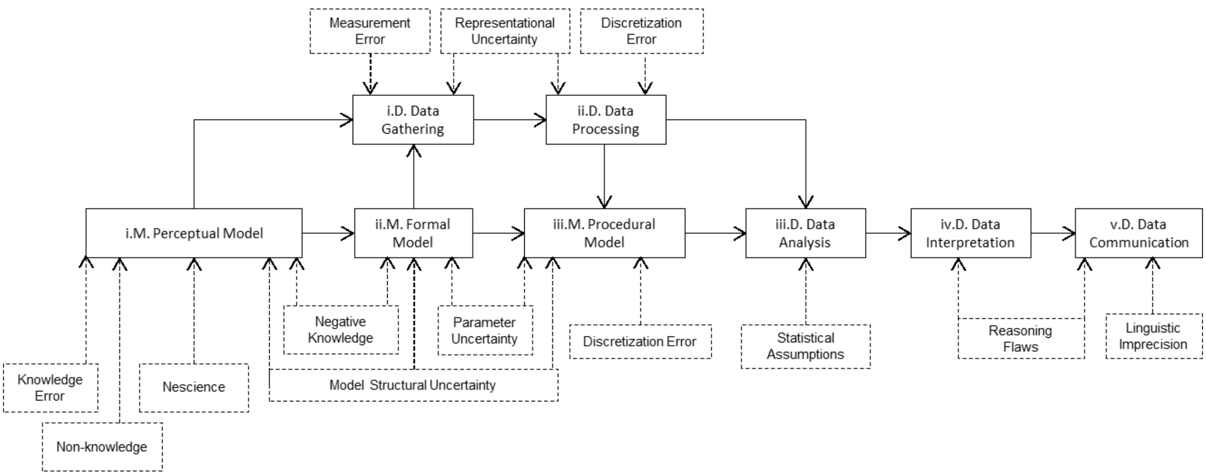

Figure 3-2: The production of knowledge underpinning PES with related sources and types of uncertainty. Perceptual models constrain the way we design data gathering and modelling. Several technical sources of uncertainty are present in the process of producing knowledge in addition to sources related to cognitive processes. Source: elaborated by the authors.

3.3.3.1 Modelling

Knowledge production always involves some sort of modelling and, in general, qualitative and/or quantitative data analysis (Figure 3-2). Here we refer to models as *any representation of human-environment processes*; every attempt to describe a system or frame a specific problem is, fundamentally, a modelling exercise. The first level of modelling, here called a "perceptual model" (Beven, 2009) (Figure 3-2, item i.M), would be a conceptual representation, i.e. a qualitative description we create when we try to conceptualize processes. At this first level, uncertainty sources relate to framing, perception, understanding and reasoning, and, therefore, potential error, non-knowledge, nescience and negative knowledge. Our perceptual models are constrained by the previous theoretical frameworks, mindsets or beliefs we carry, be they scientific or otherwise (Krueger et al., 2016; Ostrom, 2005). In general, there will be multiple ways to model a given system, i.e. there will always be model structural uncertainty (Beven, 2005). Model structural uncertainty is modulated in a conscious manner through negative knowledge, i.e. what we consider can be left out from the model for the purposes of a given study. When we establish the boundaries of our perceptual model we are creating uncertainty by actively ignoring parts of the system (Beven, 2009; Brown, 2010).

At the second level of modelling, in the "formal model" (Figure 3-2, item ii.M), representations acquire a more systematized description, leading to mathematical formulations of the system/processes under study (Beven, 2009). Of course, not all knowledge production will lead to this step – some will remain at the first level of model abstraction, i.M., and others will use data types not intended for mathematical processing. Once processes are being represented in mathematical terms, however, the formal model can be influenced not only by model structural uncertainty, but also by negative knowledge and parameter uncertainty: mathematical formulations can constrain what aspects of the system/processes are left in or out; and precise values for all system parameters will, in general, be impossible to obtain by estimation or measurement.

The third level of modelling refers to the implementation of the "procedural model" (Figure 3-2, item iii.M) using computational resources (Beven, 2009). The procedural model can be influenced by the previous sources of uncertainty and two additional ones related to data:

representational and discretization errors. The first is linked to how representative the data used are with respect to the processes of interest. The second is linked to the fact that hardware and software have numerical precision limits so that numbers may be truncated while performing calculations. In addition, many problems cannot be solved analytically, requiring so called numerical methods, the choice of which can strongly influence the final results of a model and thus is an important source of uncertainty (Kavetski et al., 2006; Seppelt and Richter, 2005).

3.3.3.2 Measurement and data analysis

Data uncertainty refers to a set of potential errors affecting the data used to represent the processes of interest, either directly or via input into models. Whenever data are used to drive or evaluate a procedural model or to test a hypothesis (derived from a perceptual model), another chain of analysis will usually be performed (Figure 3-2): data gathering (item i.D), processing (item ii.D), analysis (item iii.D), interpretation (item iv.D), and communication (item v.D). Any output from a procedural model will also constitute new data and may follow the same path. In each of these steps, additional sources of uncertainty matter.

Data gathering (Figure 3-2, item i.D) will be subject to the uncertainties of the perceptual and formal models used to define what and how much data to gather, and where and when to obtain it. In addition, data gathering is always subject to measurement error (McMillan et al., 2012). This error has a variety of components: sampling technique used, transport (e.g. water samples, microorganisms), handling (material loss, microbial or other decay, audio recording noise, unreadable field notes, and instrument damage), laboratory preparation (e.g. contamination of samples), instrument error (intrinsic precision, calibration error, and systematic error), and operation (e.g. human mistakes). Precision and sampling design, including spatial and temporal coverage, are linked to what is called representational error. This source of uncertainty is prevalent, for instance, in gridded spatial data based on the interpolation of sample points (Eigenbrod et al., 2010; Heritage et al., 2009; Phillips and Marks, 1996; Robinson and Metternicht, 2006; Sun et al., 2009), or in water sampling schemes sought to represent spatially and temporally aggregated processes (Gentine et al., 2012; Krueger, 2017; McMillan et al., 2012), or when a survey has a high nonresponse rate (Groves, 2006).

Data processing (Figure 3-2, item ii.D) is needed when raw data are in a format that is not suitable for analysis or to feed procedural models. Data processing would include conversion to different data formats, mixing different data sources, filling data gaps, classifying and eliminating outliers, transcribing interviews, coding texts, rearranging numerical data in spreadsheets, resampling raster maps, etc. Errors derived from these procedures are of a variety of types and a large literature has been devoted to their analysis in different disciplines (Biemer, 2010; Hunter et al., 1995; Kim and Ahn, 2009; Lunetta et al., 1991; Teegavarapu and Chandramouli, 2005).

Data analysis (Figure 3-2, item iii.D), in turn, refers to the choices made when using statistical procedures and methods to assemble, organize and present the data. Basic statistical metrics (e.g. mean and standard deviation), distributions and intervals are used to organize large amounts of observations and corresponding uncertainties, and graphics and formal statistical tests are used to compare values. The statistical assumptions are a common source of uncertainty in this step (Cooper et al., 2014; Zuur et al., 2010).

Data analysis is followed by data interpretation (Figure 3-2, item iv.D) and communication (Figure 3-2, item v.D). Both steps are subject to uncertainty due to flaws in reasoning, cognitive bias, and misuse of scientific information, which may include: overgeneralization, unsupported claims, oversimplification, deriving causation from correlation, strategically selecting information to support arguments, etc. (Brown, 2010). Data communication in particular is subject to an additional source of uncertainty, linguistic imprecision (Carey and Burgman, 2008).

3.4 Practical Constraints

The final uncertainty factor we explore in this paper is the practical constraints that may prevent environmental outcomes from PES to be proven. Here we refer to specific difficulties that may arise while implementing projects in the field. These difficulties permeate every step of a PES scheme (Figure 3-1) and may also be one of the drivers of model and data uncertainty (Figure 3-2). They are well known by practitioners, although frequently disregarded by theorists and decision makers proposing top-down policies. Here we discuss difficulties related to time resources, field accessibility, trained staff, data availability and accessibility, and transaction costs.

PES schemes are *time* consuming for the intermediaries in charge. Developing ES research for the scheme, negotiating with different actors, gaining acceptance in the field, building a network of trust, getting funds from payers, installing monitoring instruments, verifying contract compliance, and regularly monitoring indicators of PES impacts; all of these tasks require a lot of time. How much time is *available* to perform them effectively depends on the commitments made by the intermediaries towards both providers and payers. For instance, when a government body or public company is engaged as payer they may pressure intermediaries with deadlines to deliver results in order to match the timing of political or business processes. Development agencies may also require schemes to be adapted to a set of progress indicators to be reported annually. Providers, on the other hand, may demand implementation of activities to be in time as agreed on contract. Conservation projects are also subject to the difficulties of matching the delivery of expectations with the timing of natural processes as the latter might be much slower, e.g. the release of legacy pollutants from the system long after inputs have stooped (Powers et al., 2016).

Accessibility issues in the field may further decrease the chances of providing evidence of environmental outcomes of PES. These issues include physical difficulties, e.g. inaccessibility due to topography, difficulties in the installation and manipulation of monitoring instruments due to river morphology or seasonal floods, instrument damage by natural events, etc. They may also include social aspects, e.g. practitioners not being accepted in the field by locals, closed communities, presence of armed conflicts, etc. Although not regularly cited as obstacles, these issues can make field work unsafe or impede it completely.

When designing a PES scheme, stakeholders must be aware that it is not only a matter of time and funds, but also of having *trained technical staff* available to keep track of the changes in the field and be able to monitor and detect the desired outcomes. Although it may sound simple in theory, in practice designing and managing a monitoring system to provide rigorous ES data usually require experts and well trained staff.

Another common practical constraint is the *availability of secondary data* managed by government bodies, local associations, companies and universities. With the need to prove PES outcomes, there is a need for a baseline (Naeem et al., 2015). However, developing countries, where most PES projects take place, often do not have enough environmental data to properly characterize the initial conditions of the system upon which to detect the effects of the conservation practices. As pointed out by Ponette-González et al. (2014, p. 2) for the case of water-related ES, "the opportunity to measure water flows often arises simultaneously with the opportunity for intervention".

In addition to data availability issues, there is the *data accessibility* issue. Secondary data are seldom easily accessible as they may not be organized, or in a proper format, or open for public use. Authorities or other data holders might not want to share their data due to conflicts of interest. For instance, a water supply company could consider providing data to third parties a business risk. A government authority may not want to share data due to a perceived risk to sovereignty over natural resources. Local research centers, if they are privately owned, may consider that data gathering had a cost for them, and may thus refuse to share data free of charge. Lastly, academics may not want to share their data due to publication issues and authorship.

Most of the practical constraints reported here can be translated into different types of *transaction costs*: (a) information search; (b) negotiation; (c) contract enforcement (Dahlman, 1979). These costs are present in all steps of PES design and implementation (Figure 3-1) (Phan et al., 2017; Vatn, 2010); there are costs behind every data gathering effort, every contact made, every trust relationship built, every repair of a monitoring instrument (Jack et al., 2008). All of these demand time, money and expertise, and they must not be ignored (Muradian et al., 2010). However, payers may be willing to pay for conservation practices that can be measured and reported, e.g. number of trees planted, but they may not want to pay for research and monitoring systems. Monitoring is often the first function to be cut down under budget limits (Williams & Brown 2016).

3.5 *Illustrative Case Study*

In order to illustrate the points made in the previous sections, we explore the case of the Bolo River watershed (Valle del Cauca department, Colombia), focusing on conservation practices carried out in one of its tributaries, Aguaclara (Pradera and Palmira municipalities). This case was one of four cases studied during a 6-months doctoral research stay of the first author in Colombia from January to June 2016. The study aimed at understanding how uncertainty regarding environmental benefits of water related PES schemes were perceived and assessed by PES practitioners. The study was based on key informant interviews, informal interviews, questionnaires, non-participant observation, and review of reports and related documents from the organizations managing directly and indirectly the scheme (e.g. Calvache et al., 2012; Moreno-Padilla, 2016; Munoz Escobar et al., 2013; Uribe et al., 2009). In total, 12 key informant interviews were recorded, transcribed and coded for qualitative analysis using *NVivo* (QSR International Pty Ltd.). Fieldwork notes were processed through the same system. Participant observation was conducted while following the practitioners in their daily work, during hydrological monitoring campaigns and while negotiating with local actors. This study also includes information collected during a regional conference of water funds held in Bogotá, Colombia, in June 2016.

Interviewees were approached by the researcher by phone and email upon which the context of the doctoral project in which the collected information would be used was introduced. Most interviews were undertaken face-to-face, a few used teleconferencing. Questions started with topics related to the origins of the scheme; the main actors involved in the initial design and their motivations; and the status of the scheme in number of providers, activities performed, and total area committed for conservation so far. Subsequent questions were focused on the assessment of the effectiveness of the scheme and related methods. Topics such as practical constraints in the field and institutional problems were covered.

3.5.1 Description of the Bolo River watershed case

Public-private partnerships aiming at the protection of water resources through conservation practices became common in Colombia in the early 1990s with the creation of water user associations in several tributaries of the Cauca River (Echavarria, 2002). Conservation projects carried out by these associations have been regarded in the literature as PES or “PES-like” projects (R. L. Goldman et al., 2010; Grima et al., 2016; Munoz Escobar et al., 2013; Rodriguez-de-Francisco and Budds, 2015): water users from the downstream area of the watersheds, mainly sugarcane producers, pay a voluntary fee to fund conservation practices in the upper watersheds in order to protect the water resources upon which the downstream users depend. The associations are the intermediary entities between the payers and the providers and they have established voluntary conservation agreements directly with landowners upstream (Munoz Escobar et al., 2013).

The Bolo River water users association (ASOBOLO) is one of these cases, established in 1993 with the support of the local environmental authority (Munoz Escobar et al., 2013). Its main remit is to improve and maintain water flow regulation, and at the same time avoid sediment overloads to water bodies. Funding has been provided by water users, local companies, the local environmental authority, non-governmental organizations and international cooperation agencies. Engaged landowners receive in-kind payments, e.g. through improvements of the farm systems and through materials and resources to implement the conservation activities. River fencing, protection of springs, small-scale biodiversity corridors, and agrosilvopastoral systems are among the main conservation interventions in upstream areas.

In 2008, the Colombian sugarcane production sector boosted the creation of a *water fund* (R. L. Goldman et al., 2010) called “Fondo Agua por la Vida y Sostenibilidad” (FAVS) aimed at supporting the ongoing conservation activities by water users associations (Moreno-Padilla, 2016). The fund was launched in 2009 through a cooperation agreement involving the sugarcane production sector, The Nature Conservancy (TNC) as the main promoter of water funds (Calvache et al., 2012), two local companies, and 13 local water user associations. FAVS provides the funding and technical support, while relying on the water user associations like ASOBOLO carrying out the conservation interventions. TNC had an important role in the design and implementation of FAVS and has been influencing the water fund to work towards a more scientific approach.

3.5.2 Challenges in producing evidence of environmental benefits

When FAVS came into force, ASOBOLO was asked to follow new technical guidelines promoted by TNC, e.g. monitoring guidelines (Higgins and Zimmerling, 2013) and hydrological studies to define priority areas for conservation. For instance, TNC arranged modelling studies for the FAVS watersheds through consultancy with a local research center (Uribe et al., 2009) and received funding from USAID in 2010 to design and implement a hydrological monitoring system in one of the watersheds. A successful monitoring scheme would allow TNC and partners to communicate results to payers, attract new potential funders and support the expansion of the water fund model to other regions (Hoyos-Villada et al., 2016).

The science-based approach encouraged by TNC through the water fund model brought funding and technical assistance for the water user association; however it brought new challenges too. The hydrological modelling study arrived at ASOBOLO in the form of a report indicating the priority areas for ES conservation. It turned out that most of the priority areas identified by the report coincided with the higher lands of the watershed which had been strongly affected by armed conflicts since the 1990s and were still unsafe for fieldwork due to remnants of mistrust among the different actors. It was clear for the association that it was impossible to accomplish this prioritization defined solely on biophysical variables.

The presence of armed conflicts in the region also affected the possibilities for hydrological monitoring. Technicians looked for different watersheds to install the monitoring system but struggled to find one that was safe enough to work in. Eventually, the Aguaclara watershed (tributary of the Bolo River) was chosen. ASOBOLO made it clear that they did not have any technical staff available to maintain the sophisticated monitoring system that was going to be installed. So FAVS made an agreement with CENICAÑA, the Colombian research center for sugarcane production, to get their technical support. Since 2014, CENICAÑA has run the monitoring system consisting of several climatological stations, pluviometers, river stations with automated water level recorders and suspended solids measurements (Hoyos-Villada et al., 2016). The total implementation costs were USD 194,319 and the total annual operating costs were USD 46,880 between 2013 and 2014 (Hoyos-Villada et al., 2016). To date, this is the best case of a monitored water related PES scheme in Colombia ever documented. Still, a number of technical challenges exist.

Before the installation of the hydrological monitoring system by TNC, the Bolo River watershed had practically no local data on river discharge besides two stations managed by the local environmental authority in the lowest part of the watershed. The downstream location of the available stations makes them unsuitable for measuring any impact of conservation practices implemented along the middle to upper reaches. Climatological data relied on old stations from neighboring watersheds, although the high elevation gradient in the Bolo River watershed would require local stations to properly capture spatial precipitation variability. No data related to groundwater were available in the watershed apart from wells located in the downstream part. No extensive soil characterization was available apart from a soil classification map for the whole Valle del Cauca department made on a 1:500,000 scale (Uribe et al., 2009). In sum, it was practically impossible to establish an adequate baseline of the climatic, hydrologic and edaphic conditions prior to the commencement of the PES scheme.

The Aguaclara monitoring system was intended to be a pairwise watershed study; one watershed was taken as the control case while conservation practices were implemented in another (Hoyos-Villada et al., 2016). However, there was no way to guarantee that the control watershed would remain under any expected land use, since it was not owned by FAVS or its associates. Meanwhile, in the other watershed where conservation agreements had been made, the CENICAÑA monitoring staff found that external influences could have had an impact on their data analysis: an unexpected point contamination by a local chicken slaughterhouse happened to interfere with the suspended solids sensor creating odd patterns in recorded data; unexpected suspended solids spikes were misinterpreted until the staff found out that a local farmer was crossing his cows in the creek every day; flash floods were continuously bringing debris and sediments to the gauging station making it impossible to record the water level during such events; a local landowner who took part in the project decided to open the area he had set aside for conservation to his horses releasing a considerable amount of sediments close to the monitoring station. In addition, the strong 2015 El Niño event affected several conservation schemes in the region. There was a high percentage of mortality among seedlings and young trees planted and several forest patches set aside for recovery were taking much more time than expected to regain strength.

3.5.3 Uncertainty sources in the Bolo River watershed case

For more than 20 years, ASOBOLO has worked in the Bolo River watershed based on trust and reputation built over time. Landowners upstream were engaged largely thanks to the environmental awareness created during those two decades. The payers, in turn, demanded a report with indicators related to the activities performed with their money, like total number of trees planted, total area under recovery, and so on. Most of them were not expecting concrete numbers related to the effects of those activities on river discharge, sediment load, nutrient concentration, etc. However, evidence of ES improvement became important with the implementation of the water fund model, and uncertainties suddenly started to play a bigger role.

As described previously, the Bolo River watershed did not have enough environmental data to characterize its hydrological and ES baseline (non-knowledge), a common case in many Latin-American watersheds. Without this information, it is hard to describe the initial conditions of the biophysical system with confidence and to calibrate a model capable of representing its behavior (leading to model structural/parameter uncertainty). Local information on specific vegetation-soil-water dynamics is not available, and neither are studies of these dynamics under varied land cover/land use categories or vegetation types/stages of recovery (parameter uncertainty). Effects of land use change on hydrology are usually extremely site-specific and general assumptions can be misleading (non-knowledge/knowledge error) (Bruijnzeel, 2004; Calder, 2002; Porras et al., 2008). Therefore, without local data it is difficult to predict to which extent farm conservation practices or forest recovery would affect water flow during dry and wet seasons, and sediment transport and loads. Even with this information at hand, it would still be difficult to extrapolate point information to the entire watershed (representational error). Land use and cover maps, regularly used in models for ES valuation, are known to have significant representational and discretization errors (Dong et al., 2015).

In addition to data issues, defining conservation priority areas solely by biophysical factors and disregarding social ones may lead to irrelevant results. In the presented case, as social conditions were not integrated in the prioritization model, it turned out impossible to target the indicated areas due to the presence of armed conflicts (negative knowledge). Social factors also influence many other aspects of a PES scheme, for instance: social norms behind farm lease, tenure and irregular occupation trends influence the degree of engagement of actors (leading to high transaction costs of negotiation); lack of trust and confidence among actors due to the armed conflict legacy may constrain field studies (model structural uncertainty); local behavioral patterns influence the risk of having monitoring equipment stolen or damaged (leading to measurement errors).

The influence of external variables on the PES scheme (consequence of an open system) in the form of omitted processes is associated with nescience or non-knowledge that may lead to several measurement errors, e.g.: the El Niño influence on the rate of mortality of planted trees; non-compliance by landowners and its effect on monitoring signals; intense rainstorms generating floods that damage monitoring equipment; unexpected influence of chicken tissue contamination on the sediment sensor.

Lastly, uncertainty in the administrative domain, including legal and financial uncertainty, is a common practical constraint associated with high transaction costs. In this case, by being a voluntary initiative with budgets calculated on an annual basis, it has been unfeasible for the association to offer continuous payment and even pay farmers proportionally to their opportunity cost. The same uncertain financial future did not allow the association to afford the sophisticated monitoring system or to pay the technical staff to manage it. The possibility of implementing one in Aguaclara watershed only became reality through a development agency grant and the partnership with TNC and local research centers, which are favorable conditions not found in most other cases.

3.6 Propositions for Uncertainty Management in PES

As a conservation mechanism that deals with complex HES and is, at least in theory, subject to evidence of "service provision" (Wunder, 2005), PES are highly demanding in terms of data and models, and hence vulnerable to the associated uncertainties. Even the "simple yet rigorous" scientific principles and guidelines proposed by Naeem et al. (2015) are, in practice, not so simple if uncertainty and transaction costs are taken into account.

Specifically, if stakeholders frame their expectation of PES as improvements of ES in terms of supposedly "factual numbers", then uncertainty affecting data gathering, processing, analysis and interpretation should be a major concern for PES effectiveness. In practice, procedural models, like hydrological and sediment transport models, have been used in PES schemes to define where, when, what types of and how much conservation interventions will be needed to achieve some environmental outcome (Crossman et al., 2013; Quintero and Estrada, 2006; Ruckelshaus et al., 2015; Tallis and Polasky, 2009). If practitioners then expect to achieve the numbers provided by the models and manage to convince potential payers based upon them, then model uncertainty may compromise the effectiveness of the schemes.

In order to manage uncertainty, we propose a modification of the *typical* step-by-step PES process (Fig. 1) towards an adaptive management cycle (Haasnoot et al., 2013; Murray and Marmorek, 2004; Smith and Porter, 2010; Williams and Brown, 2016) including considerations of how to tackle uncertainty issues (Fig. 3).

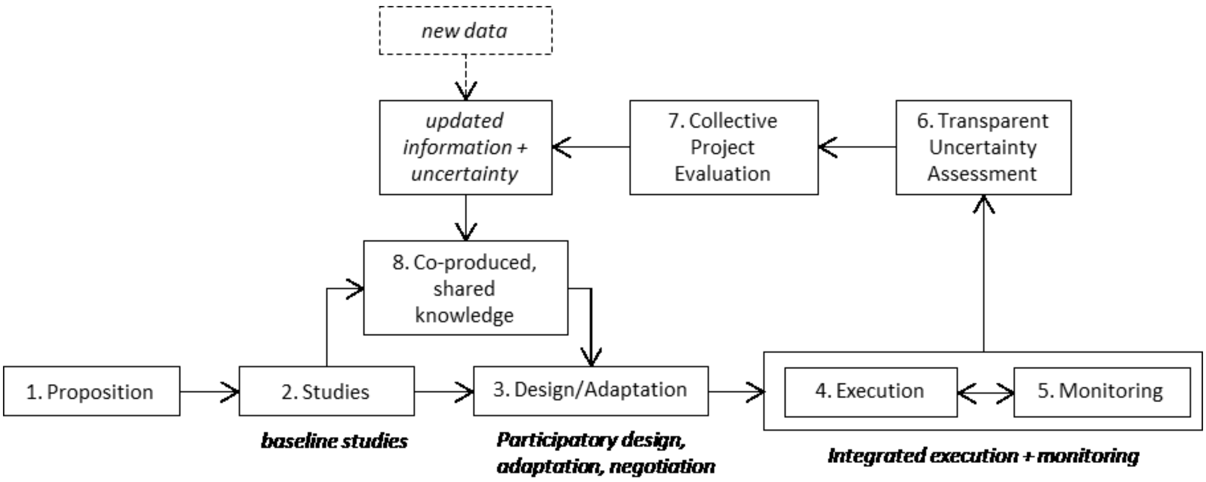

Figure 3-3: A modification of the typical step-by-step PES management taking into consideration uncertainty and adaptation strategies. Step 1 and 2 follow descriptions made for Figure 3-1; entering the loop of management, step 3 refers to the design of strategies, negotiation and project adaptation stressing the need for greater stakeholder participation; steps 4 and 5 emphasize that execution ideally should be done in parallel with monitoring; step 6 stresses the importance of an assessment of uncertainty sources in a transparent way among stakeholders; step 7 refers to a general evaluation of the scheme ideally by stakeholders; new sources of external data are continuously feeding the loop and should be incorporated to update information about the system; step 8 stresses the importance of a co-produced and shared knowledge base as input for adaptation of plans as needed. Source: elaborated by the authors.

Moving from a linear model of a typical PES (Figure 3-1) to an adaptive version (Figure 3-3) requires stakeholders to be committed to a transparent and participatory process. In this adaptive model, tackling the environmental issue at hand is recognized as a loop that is continuously permeable to new information and surprises shared among the stakeholders. Whenever possible, there is an explicit assessment of uncertainty sources and an emphasis on a collective project evaluation. This adaptive model implies that PES goals and therefore contracts can be re-negotiated in a participatory manner according to new knowledge about the HES.

If environmental monitoring is feasible, it should be done in tandem with PES implementation. However, relevant knowledge about the HES is produced not only by scientific methods, but also by non-scientific knowledge through participation of those who actually live in the area under management (Krueger et al., 2012). For instance, there are several explanations for environmental events in a watershed that could be easily understood through communication with locals instead of obtaining data from sophisticated monitoring equipment. In our illustrative case, a local land owner was the one who found out that the turbidity peaks observed at the monitoring point was being caused by the cows crossing one of the tributary streams every afternoon. Involving the local community in the actual environmental monitoring can also increase the sense of participation and ownership of the process which could in turn increment the chances of acceptance and long-term survival of the scheme. An adaptive approach to PES that accounts for uncertainty through an open dialogue with stakeholders and integrates providers' standpoints, instead of a top-down measure set up among only intermediaries and payers, may produce a more legitimate process (Kwayu et al., 2014; Petheram and Campbell, 2010).

Taking uncertainty seriously means that expectations of PES schemes should be balanced against the costs of monitoring and predicting the outcomes. There is a need to discuss among the stakeholders the "value of information" (Williams and Brown, 2016), i.e. how much we gain from investment in getting more information about the system under management. In this context it is important to recognize that adaptive management would imply other types of transaction costs related to participatory and negotiation processes and frequent reviewing cycles.

A potential risk of the uncertainty-inclusive PES management strategy outlined so far is that the uncertainties exposed become so large that payers would not be willing to pay for such uncertain services anymore. If this is the case, then perhaps uncertainty can be used as an opportunity to open up discussion about alternative conservation strategies. However, we should not forget that payers may not engage in PES schemes only to see proof of environmental benefits, but following other motivations or preferences. For instance, companies could engage just to fulfill their corporate socio-environmental policies. Citizens acting as payers may participate motivated by a sense of community belonging. Governments might engage just to be seen to be "doing something" about environmental issues. Nevertheless, in these cases too, being explicit about uncertainty will help to expose alternative motivations and lend transparency to the conservation debate in those particular places.

3.7 Conclusion

Conceptualizing PES as transactions of "units of service" is unrealistic; the complexities of HES defy such simple compartmentalization. Nevertheless, the ES paradigm led to the privileging of PES schemes over other conservation strategies, while the considerable uncertainties related to demonstrating environmental benefits have been downplayed. But there is no escape from uncertainty, with the potential for losses, harm or undesired consequences when outcomes are not as expected. In designing PES schemes, we should therefore explicitly address uncertainty in order to have a clearer picture of potential ways to progress, cope with and adapt to unforeseen circumstances, and eventually ensure the long term viability of the conservation projects. However, we must not forget that uncertainty may be used selectively, downplayed or amplified in politics to suit vested interests or keep unequal power relations. We propose that PES stakeholders should invest time and effort in understanding and exchanging knowledge about the complexity of the HES they are dealing with, and make uncertainties openly explicit in the process of proposing, bargaining and designing PES mechanisms. Arguably, transparent treatment of uncertainty is fundamental to managing expectations, build trust among actors and maintain credibility of PES practitioners. If recognizing and accounting for uncertainty is to threaten the success of PES schemes, then uncertainty can be seen as an opportunity to open up dialogue about alternative ways of achieving the conservation goals.

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4 Efforts and constraints to demonstrate additionality of payments for watershed services: Insights from Colombia and Brazil

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ABSTRACT

The effectiveness of Payments for watershed services (PWS) has been put into question due to very scarce evidence of impact so far. There is now a growing international call for impact evaluation, and a core component of it has been additionality, for which baselines, monitoring and case-control are considered essential. The literature is still poor on empirical studies describing the causes behind the lack of evidence of additionality. Here we empirically explore and discuss technical and institutional aspects of seven PWS schemes in Colombia and Brazil that reflect the efforts made and the constraints faced to assess their impact. We found that PWS intermediaries are gradually responding to this increasing demand for impact evaluation. Almost all schemes are implementing monitoring systems of varied technical quality. The collaborations between intermediaries and local research centres in the monitoring and evaluation systems are indicators of this increasing concern. However, in the majority of the

schemes studied, no baselines of important environmental variables and no monitoring protocols were established at beginning, which is now severely compromising evidence of additionality. Assessing additionality as promoted in the literature, i.e. clearly defining unequivocal effects of interventions has been arguably infeasible in most cases so far.

4.1 Introduction

Environmental conservation has seen the rise and fall of several worldwide conservation paradigms. Since the mid-2000s, payments for ecosystem services (PES) became the most recent trend and its rise was supported by claims of PES being more effective and efficient than previous modes of intervention (Ferraro and Kiss, 2002; Muradian et al., 2013; Wunder, 2005). The efficiency claim is based on the argument that direct payments are less costly and more direct towards conservation targets than other conservation strategies (Ferraro and Kiss, 2002; Ferraro and Simpson, 2002). However, almost two decades of PES projects worldwide calls into question their efficiency as well as their effectiveness in delivering the target ecosystem services (Boerner et al., 2017; Naeem et al., 2015).

The call for evidence of effectiveness is relatively new in environmental conservation (Baylis et al., 2015; Ferraro, 2009; Ferraro and Pattanayak, 2006), but has some history in the Public Administration sector. Beginning in the 1970s, a trend towards more accountable and efficient policies and projects in several fields led to the emergence of “evidence-based policy making” (Mceldowney, 1997; Sanderson, 2002). Under this paradigm, the evaluation of the impacts of policies and projects is of central importance, including one of its key aspects, *additionality*, i.e. the effect of an intervention against the null hypothesis or counterfactual (Georghiou, 2002). In order to assess additionality, baselines are essential (Gillenwater, 2012) along with a monitoring system and case-control that are able to capture the changes in the target system and the benefits gained through intervention (Naeem et al., 2015). The core idea is to be able to establish unequivocal causal links between the observed changes and the intervention, and more specifically to be able to differentiate which part of those changes can actually be attributed to the intervention and which to other (external) factors (Gertler et al., 2011).

Assessing additionality has been a long struggle among those working with Clean Development Mechanisms - CDM (Ellis, 2003; Gillenwater, 2012; Schneider, 2009); and more recently also among those working with PES schemes in general (Boerner et al., 2017). Particularly in the case of water-related PES schemes, here called payments for watershed services (PWS), evidence of their impact in terms of water provision and water quality has been very scarce or missing completely (Ponette-González et al., 2014; Ina Porras et al., 2013).

There are many reasons for the lack of impact evidence in the PWS context. The literature on PWS has identified several challenges in demonstrating additionality, ranging from the complexity of human-environment systems and the related lack of knowledge about these systems to the most basic problems of technical capacity, cooperation, and transaction costs (Barnaud and Antona, 2014; Boerner et al., 2017; Lima et al., 2017; Muradian et al., 2010; Norgaard, 2010; Phan et al., 2017; Vatn, 2010). In addition, many studies have increasingly raised awareness of poor monitoring strategies, absence of baseline data and absence of a comparable 'non-intervention' scenario in most PWS schemes (Carpenter et al., 2009; Echavarria et al., 2004; Martin-Ortega et al., 2013; Naeem et al., 2015; Postel and Thompson, 2005).

Raising evidence for demonstrating additionality in PWS requires a complex methodological design, mainly due to the large number of variables to be considered and the multi-dimensional scale (both spatial and temporal) of the problem at stake. An additional complication is that these interventions deal with the relationship between land use and land cover (LULC) and hydrological dynamics (Guswa et al., 2014). The assessment of the impacts on such relationship therefore requires the measurement of changes at these two components (LULC and hydrologic variables). Since watersheds are complex systems, with high levels of spatial and temporal heterogeneity, the assessment of aggregated impacts (at the watershed level) depends also on the spatial distribution of measurements points (of water flows and quality) and the frequency of data gathering. There are three main dimensions (associated with scales) relevant for the assessment of additionality in PWS: (a) the evaluation of compliance at the property level; (b) the assessment of land use changes (at the watershed level) and (c) the assessment of hydrological features (at the watershed level). The latter two require the establishment of control groups. The dimension (c) is the most complex, therefore, technical aspects regarding choice of variables and representativeness of measurements are of strategic importance for detecting the expected system changes.

Although these technical challenges are well discussed, the literature is still poor on empirical studies describing the efforts made by practitioners so far, the institutional reasons for these efforts, and the constraints found in practice that hinder the evidence of additionality. In this paper, we empirically explore and comparatively discuss the technical and institutional aspects of seeking to demonstrate additionality in seven PWS schemes in Colombia and Brazil. We describe and compare the institutional context of each scheme, along with the status of key technical components. We discuss the influence of the political-institutional arrangements on the quality of the schemes' technical design and, therefore, on their potential to demonstrate additionality in the long-term.

4.2 Methods

This study draws together material from seven PWS schemes in Colombia and Brazil, including government and non-government driven initiatives (Table 4-1). In Colombia, four schemes were studied: "Agua Somos" (Chisacá and Mugroso river watersheds - tributaries of Tunjuelo river; located in Usme, Bogotá D.C.); Asociación de Usuarios de Agua del Río Bolo – "ASOBOLO" (Aguaclara river watershed - tributary of Bolo River; located in Pradera and Palmira municipalities, Valle del Cauca Department); Compensación por Servicios Ambientales Hidricos Cuenca del Río Cali - "CSAH Cali" (Felidia and Pichindé rivers watersheds – tributaries of Cali River; located in Cali municipality, Valle del Cauca Department); and "CuencaVerde" (Chico river watershed - tributary of Riogrande River; located in Belmira municipality, Antioquia). In Brazil, three schemes were studied: "ProdutorES de Água" (Benevente river watershed, located in Alfredo Chaves municipality, Espírito Santo state); "Conservador das Águas" (Posses and Salto rivers watersheds, Extrema municipality, Minas Gerais state); "Projeto Piloto Produtor de Água no PCJ" (Cancã and Moinho rivers watersheds, in the municipalities of Joanópolis and Nazaré Paulista, São Paulo state).

Table 4-1: Description of the seven PWS schemes. Literature references, watershed location, actors involved in political mobilization, managers, major payers, funding source, year in which conservation interventions started, and number of contracts signed as of the end of the fieldwork (only in the referred watershed).

Scheme, Main References	Watershed, Department, Country	Political mobilization	Intermediary (Manager)	Major payers (projects, contracts, donations)	Funding Source	Year	# of contracts in this watershed
Agua Somos (Goldman-Benner et al., 2012)	Chisacá and Mugroso Rivers, tributary of Tunjuelo River, Dept. of Cundinamarca, Colombia	Latin-American Alliance for Water Funds; TNC	Fundación Patrimonio Natural	Bavaria/ SabMiller, EAAB, SDA, TNC, IADB, Coca-Cola/FEMSA	private sources, natural resources royalties, municipal funds	2013	25 (as of February 2016)
ASOBOLO (Moreno-Padilla, 2016; Munoz Escobar et al., 2013)	Aguaclara river, tributary of Bolo River, Palmira Municipality, Dept. of Valle del Cauca, Colombia	CVC, ASOCAÑA	ASOBOLO	Water users, ASOCAÑA, CVC, Syngenta, RioPaila y Castilla, Mayagüez, Pradera municipality, AcuaValle, TNC	private sources, natural resources royalties	2011 (1)	56 (as of June 2016)
CuencaVerde (Gómez-Ochoa, 2016)	Chico River, tributary of Río Grande Reservoir, Belmira municipality, Dept of Antioquia, Colombia	TNC, EPM	CuencaVerde	EPM, Medellín Municipality, TNC, Coca-Cola FEMSA, IADB, GEF, AMVA, CORNARE, Nutresa, Postopon, Grupo Argos (2)	private sources, natural resources royalties	2015	22 (as of June 2016)
CSAH Cali (Fondo Patrimonio Natural et al., 2014)	Felidia and Pinchindé rivers, tributaries of Cali River, Cali Municipality, Dept. of Valle del Cauca, Colombia	Fundación Patrimonio Natural	AcuaCali.co	The Netherlands government, CVC, EMCali, ASOCAÑA	international fund, private sources, natural resources royalties	2013	46 (as of June 2016)

Conservador das Águas (Pereira, 2013)	Posses and Salto Rivers, tributaries of Jaguari River, Extrema Municipality, Minas Gerais, Brazil	Extrema municipality; ANA; TNC	Department of Urban Services and Environment (DSUMA) of Extrema municipality	Tax payers through municipal fund; Minas Gerais State Secretary of Environment; PCJ Committee; National Water Agency	municipal funds, water users committee funds	2006	161 (as of end of 2013)
Projeto Piloto PCJ (Padovezi, 2013)	Moinho River, tributary of Atibainha River, Nazaré Paulista Municipality; Cancã River, tributary of Cachoeira River, Joanópolis Municipality, São Paulo State, Brazil	TNC, Secretaria de Meio Ambiente de SP, ANA	PCJ Project Management Unit (UGP)	Water users through the watershed committee, GEF	water use fees, water users committee funds	2009	41 (as of end of 2013)
ProdutorES de Água (Instituto Estadual de Meio Ambiente do Espírito Santo, 2014)	Benevente River, Alfredo Chaves Municipality, Espírito Santo State, Brazil	Environment and Water Resources Institute of the Espírito Santo State (IEMA)	IEMA	Water Resources Fund of the Espírito Santo State (FUNDAGUA)	natural resources royalties	2009 (ended in 2014)	138 (as of end of 2014)

Abbreviations: CVC- Corporación Autónoma Regional del Valle del Cauca; FPN- Fundación Patrimonio Natural; TNC- The Nature Conservancy; ASOCAÑA- Asociación de Cultivadores de Caña de Azúcar de Colombia; ASOBOLO – Asociación de Usuarios de las Aguas Superficiales y Subterráneas de la Cuenca del Río Bolo; EAAB – Empresa de Acueducto, Alcantarillado y Aseo de Bogotá; SDA- Secretaria Distrital de Ambiente; IADB – Inter-American Development Bank; EPM – Empresas Públicas de Medellín; GEF – Global Environmental Facility; EMCali – Empresas Municipales de Cali; ANA – Agência Nacional de Águas; DSUMA – Departamento de Serviços Urbanos e Meio Ambiente, Prefeitura de Extrema; PCJ – Comitê das Bacias dos Rios Piracicaba, Capivari e Jundiaí; UGP – Unidade de Gestão do Projeto PCJ; IEMA – Instituto Estadual de Meio Ambiente e Recursos Hídricos do Espírito Santo. (1) Refers to the year in which activities started in Aguaclara watershed only. ASOBOLO itself was launched in 1993 and started working in other regions first. (2) Other payers are also informed as allied organizations (de la Ossa-Posada and Montoya-Velilla, 2017).

4.2.1 Field work

The study was based on semi-structured interviews, informal interviews, participant observation, and literature reviews of reports and related documents from the organizations managing and/or supporting the schemes, in addition to scientific papers describing the cases. Two field campaigns were conducted in order to collect primary data: July to December 2013 in Brazil; and January to June 2016 in Colombia. Participant observation was done while following intermediaries in the field and while attending a major conference of PWS stakeholders involving five of the studied schemes among others (June 13th to 17th 2016, Bogotá D.C.). Interviews were done with PWS managers and technicians working in the field (Table 4-2). They were recorded, transcribed and qualitatively analysed through coding.

Interviews started with questions regarding the reasons why the scheme was created; the main actors involved in the initial design; motivations; and the status of the scheme in terms of number of providers, activities performed, and total area committed for conservation so far. Subsequent questions revolved around the arguments used to engage payers and providers; and then focussed on the methods used to assess the scheme's effectiveness, including monitoring systems, case control and baseline data. Questions also touched upon the difficulties managers and technicians were facing in engaging providers and payers, overcoming institutional problems, obtaining collaboration, and auditing the scheme.

Here we consider PWS intermediaries as "actors who take on roles that connect and facilitate transactions between buyers and sellers" (Huber-Stearns et al., 2013, p. 105). We divided intermediaries in two groups in order to clarify their roles: those in charge of political mobilization for the adoption of the PWS scheme on the one hand, and managers of the scheme on the other hand (Table 4-1). Political mobilization here refers to building momentum, motivating and gathering stakeholders, and raising initial funds to design and establish the PWS scheme. Managers are those intermediaries in charge of running and managing the scheme, performing activities such as marketing, enlisting actors, negotiating, paying, and monitoring. In the schemes studied, providers are usually small-scale landowners living in the upstream areas of the watersheds and payers are mostly private companies, public companies and environmental authorities.

Table 4-2: Methodological details for each scheme under study

Scheme/ Methods	Agua Somos	ASOBOLO	Cuenca Verde	CSAH Cali	Conservador das Águas	Projeto Piloto PCJ	ProdutorES de Água
Duration of fieldwork (months)*	2	2	1	1	0,5	0,5	1
Number of semi-structured interviews	12‡	12‡	10‡	6	5	5	14
Organizations interviewed	Patrimonio Natural, TNC, EAAB	ASOBOLO, ASOCAÑA, TNC, CENICAÑA	CuencaVerde, TNC, EPM	Ecoforest, AcuaCali.co, CIPAV	Extrema municipality TNC, IEF/MG	Joanópolis municipality, CATI Joanópolis, Nazaré Paulista Agriculture Department, PCJ, TNC Local reforestation company	IEMA, SEAMA, INCAPER, IDAF, Alfredo Chaves municipality, Ibio
Reports, theses, and scientific papers reviewed	(Calvache et al., 2012; Goldman-Benner et al., 2012)	(A. R. L. Goldman et al., 2010; Hoyos-Villada et al., 2016; Lima et al., 2017; Moreno-Padilla, 2016; Munoz Escobar et al., 2013)	(Calvache et al., 2012; de la Ossa-Posada and Montoya-Velilla, 2017; Goldman-Benner et al., 2012; Gómez-Ochoa, 2016)	(Fondo Patrimonio Natural et al., 2014; Fundación CIPAV, 2011; Galindo, 2016)	(Chiodi, 2015; Pereira, 2013; Zanella et al., 2014)	(Chiodi, 2015; Marçal, 2013; Padovezi, 2013; Taffarello et al., 2017, 2016a, 2016c, 2013)	(Chiodi, 2015; Sossai et al., 2013; Zanella et al., 2014)

*Comprising visits to the conservation sites, farms with PWS contracts, authorities' offices, and other stakeholders' offices. ‡Five of those refer to all schemes under the *Water Funds Partnership*, including Agua Somos, CuencaVerde and ASOBOLO, i.e. the same interviews are used to explore each of the three schemes in these five cases. Abbreviations: IEF/MG – Instituto Estadual de Florestas de Minas Gerais; CATI – Coordenadoria de Assistência Técnica Integral; SEAMA – Secretaria de Estado de Meio Ambiente e Recursos Hídricos do Espírito Santo; INCAPER – Instituto Capixaba de Pesquisa, Assistência Técnica e Extensão Rural; IDAF – Instituto de Defesa Agropecuária e Florestal do Espírito Santo; Ibio – Instituto BioAtlântica.

Table 4-3: Target ES, activities performed in the field, type of payment and payments for each PES scheme in the specified watershed (these schemes may be also present in other watersheds but this study is limited to the mentioned ones).

Scheme	Watershed area (ha)	Target ES	Conservation interventions	Types of Transfer	Contract conditions for land holders
Agua Somos	Chisacá and Mugroso 8,245*	Water quality and provision, sediment retention	River fencing, tree planting, cattle rotational grazing systems	Energy saving wood stoves, cattle drinking fountains, materials for fences, seedlings	Labour for fencing; no disturbance in forest recovery area; maintenance of fences
ASOBOLO	Aguaclara 2,126†	Water flow regulation, sediment retention, water provision	River fencing, spring protection, tree planting, forest protection, farm septic tanks, biodigesters, agrosilvopastoral systems, cattle rotational grazing systems, live fences and conservation strips	Material for fences, seedlings, septic tanks, biodigesters, financial support for implementing forest reserves, community vegetable gardens, fruit trees, environmental education in schools, capacity building with local associations, technical assistance, farm mapping	Labour for fencing; no disturbance in forest recovery area; maintenance of conservation strips and fences; cattle rotation
CuencaVerde	Chico 17,172‡	Water quality	River fencing, forest protection, spring protection, forest restoration, tree planting, farm septic tanks, live fences	Cattle drinking fountains, materials for fences, bridges for cattle, seedlings, 'wood banks' for fuel, energy saving wood stoves, domestic sewage treatment systems	No disturbance in forest recovery area
CSAH Cali	Felidia 6,635§ Pichindé 5,272§	Water quality and provision, sediment retention	River fencing, forest protection, spring protection, conservation strips, live fences	Cash, materials for fences, seedlings, technical assistance, biodigesters, farm mapping, fruit trees, 'protein banks' for cattle	No disturbance in forest recovery area
Conservador das Águas	Posses 1,200& Salto 4,500&	Water quality, biodiversity conservation, CO_2 uptake	Forest protection, vegetation recovery, conservation barriers and terraces, biodigesters for waste and water supply tanks	Cash, labour and material for fences, seedlings planting and plant maintenance	No disturbance in forest recovery area
Projeto Piloto PCJ	Moinho 1,757# Cancã 1,141#	Improved water yield and controlled diffusive pollution from agriculture	Forest protection, vegetation recovery, conservation barriers	Cash, labour and material for fences, seedlings planting and plant maintenance	No disturbance in forest recovery area
ProdutorES de Água	Benevente 12,070@	Water quality and provision, biodiversity, soil erosion reduction, CO_2 uptake	Forest protection	Cash	No deforestation in forest area

Sources: *Calculated from digital elevation map, upstream Chisacá reservoir; [‡]Calculated from digital elevation map, upstream confluence with El Hato stream; [†]Calculated based on watershed shapefile provided by CENICAÑA; [§]Fondo Patrimonio Natural et al., 2014; [&](Pereira, 2013); [#](Padovezi, 2013); [@](Instituto Estadual de Meio Ambiente do Espírito Santo, 2014)

4.2.2 Brief description of case studies

Agua Somos is a private-public partnership for conservation launched in 2008 in Bogotá (Goldman-Benner et al., 2012). It is a “water fund”– a water-related PES based on trust funds widely promoted by the NGO “The Nature Conservancy” (TNC) and its partners (Bremer et al., 2016a; Calvache et al., 2012; R. L. Goldman et al., 2010). Agua Somos was established through a cooperation agreement among TNC, the local water supply company (Empresa de Acueductos y Alcantarillado de Bogota – EAAB), Bavaria Foundation, the National Parks Authority (PNNC), and the NGO Fundación Patrimonio Natural (FPN). The goal of Agua Somos is to protect and manage the watersheds that feed the water supply system of Bogota (Agua Somos and Alianza Latinoamericana de Fondos de Agua, 2014), focusing specifically on watersheds connected to the two major páramos in the region: Sumapaz and Chingaza. Agua Somos is managed by FPN and technically supported by TNC.

ASOBOLO is a water user association (WUA) concerned with the conservation of water resources and irrigation management among sugarcane producers of the Bolo River watershed, Valle del Cauca Department, Colombia (Echavarria, 2002; Lima et al., 2017; Munoz Escobar et al., 2013). ASOBOLO works as the intermediary entity between payers and providers. Voluntary conservation agreements have been made with the landowners in the upper watersheds in order to protect springs and creeks. Water users from the downstream area pay a voluntary fee to fund the conservation practices (Munoz Escobar et al., 2013). ASOBOLO was established in 1993 and has been supported by the local environmental authority (CVC) ever since. It also receives funds and technical support from local companies, NGOs and international cooperation schemes, such as the Latin-American Alliance for Water Funds (Lima et al., 2017). Since 2009, ASOBOLO has been associated with the water fund “Fondo Agua por la Vida y Sostenibilidad” (FAVS) (Moreno-Padilla, 2016). The scheme has the technical support of the local sugarcane research centre (Centro para la Investigación de la Caña de Azúcar de Colombia – CENICAÑA) and TNC.

CuencaVerde is a private-public partnership following the water fund model, created in 2013 in Medellín and aiming at promoting conservation in the watersheds that feed the water supply system of the city (Bremer et al., 2016a; de la Ossa-Posada and Montoya-Velilla, 2017). It is the only water fund case in Colombia that was established as a legal entity with its own administrative body, while the other cases are managed by existing organizations, such as associations or NGOs. The scheme was initially promoted by the local public services company (Empresas Públicas de Medellín – EPM) and TNC. In addition to the two initial actors, the partnership now includes the Medellín City Hall, the local environmental authority (CORNARE), the metropolitan public authority (Area Metropolitana Valle de Aburrá - AMVA) and five other companies (Gómez-Ochoa, 2016). It also receives support from the Latin-American Aliance for Water Funds. Since mid-2014, CuencaVerde has been working in watersheds that provide water for the city of Medellín.

CSAH Cali: concerns with potential water shortages led local stakeholders in 2010/2011 to design a PES instrument that was locally named "compensation for hydrologic environmental services" (CSAH in Spanish) in order to protect the Cali watershed (Fondo Patrimonio Natural et al., 2014). Main institutional actors which took part in the process were the regional environmental authority (CVC), the environmental bureau of Cali City Hall (DAGMA), Farallones de Cali National Park (PNNFC), the local public services company (EMCALI) and the energy supply company (EPSA). Design and implementation of the scheme was supported and stimulated by FPN through Dutch funding for a 5-year project called "Conservation Incentives". A local research centre (Centro para la Investigación en Sistemas Sostenibles de Producción Agropecuaria – CIPAV) was engaged in the process as technical support. The group of initial stakeholders later invited the representatives of the local community aqueducts to take part as the central managers of the scheme (Fondo Patrimonio Natural et al., 2014).

The project **Conservador das Águas** originated from a series of previous conservation intents dating back to 1996 when a group of municipalities from the South of Minas Gerais State came together to implement local actions for water resources protection using federal funding from the Ministry of Environment. With accumulated experience from these previous intents and with the support from ANA's "Water Producer" programme, the Conservador das Águas begun to be designed (Chiodi, 2015) and was launched in 2005 by the Extrema municipality. It was the first law to regulate water-related PES schemes in Brazil. The project is managed by the municipal environmental authority which is in charge of the definition of priority areas, setting contracts with farmers, monitoring and implementing interventions (Chiodi, 2015; Zanella et al., 2014). The goals of the project are: to increase forest cover; to implement ecological corridors; to decrease the level of rural diffuse pollution; and to disseminate the concept of integrated management of vegetation, soil and water (Chiodi, 2015).

Projeto Piloto Produtor de Águas no PCJ: the project was initially proposed by one of the technical groups of the PCJ watersheds committee (PCJ stands for the names of the rivers: Piracicaba, Capivari and Jundiaí). The project was created in 2006 (Chiodi, 2015). The idea was to implement, with certain flexibility, the model design of ANA's Water Producer programme. Three organizations were key actors in the creation of the Projeto Piloto PCJ: TNC, ANA, and the Secretary of Environment of the São Paulo state, SMA/SP. Other important actors were representatives from the local municipalities of Joanópolis, Nazaré Paulista and Extrema. The payment for ES providers is funded with the water user fees and additional funding was obtained through different sources, including GEF. TNC also supports the project. The goal of this pilot project is to incentivize the rural landowners to support the protection and recovery of local springs through cash payments. Interventions are focused on practices aiming at protecting forest fragments, restoring forest cover and protecting the soil (Gebara et al., 2012).

The **ProdutorES de Água** project was proposed in 2005 by representatives of the Environmental Institute of the Espírito Santo state, linked to the local Secretary of the Environment (IEMA/SEAMA). It had a strong incentive from two NGOs, Instituto BioAtlântica (Ibio) and TNC. While an initial proposal for GEF funding was submitted through the World Bank, another one was put in practice sooner with great interest from regional politicians. In 2008 the programme was officially launched together with a specific fund for water resources protection, FUNDÁGUA, by the Espírito Santo State Law n° 8995 (23/Sept/2008). The programme paid farmers with significant forest fragments in their lands with the intention of recognizing and rewarding the farmers due to the provision of ES. However, no actual additionality was created as the project paid farmers that already preserved good vegetation cover on their properties. The project was coordinated by the state environmental agency and ended in 2012 (Chiodi, 2015; Zanella et al., 2014). Three types of ES were considered: water availability and quality maintenance and improvement; biodiversity maintenance and increment; reduction of erosive processes; carbon emissions uptake.

Table 4-1 and Table 4-3 provide additional details about the actors involved, number of contracts, contract conditions, type of transfer, and type of conservation practices. Although these schemes may be present in other local watersheds, for the purpose of this study we only consider the watersheds mentioned in Table 4-1 and Table 4-3.

4.3 Results

4.3.1 Current efforts to demonstrate additionality

Contract Compliance: Contract compliance (CC) implies that landowners maintain the conservation interventions undertaken during the projects. CC monitoring emerged as an important component in almost all schemes studied. Typical indicators of CC monitoring are the frequency of intermediaries' visits to intervention sites and the quality of mapping the interventions. In the Colombian cases, the frequency of visits was at least 1 per month (Table 4-4). In the Brazilian cases, it varied: Conservador das Águas, every 2 months; Projeto Piloto PCJ, twice per year; and ProdutorES de Água, once per year. Six of the seven cases studied produced maps of the properties with conservation contracts with scales from 1:4,000 to 1:2,000 (Table 4-4). Several cases used aerial photography to characterize the LULC at the property level before interventions. Whenever aerial photography was not available, the intermediaries made use of images obtained from Google Earth combined with GPS measurements in the field. The number of feature types mapped varied in each case. Updates were usually done by using information collected during field visits. The most important features in these maps are the interventions made by the scheme and their extent.

Table 4-4: Monitoring of contract compliance (CC) and conservation interventions at property scale.

Scheme	Avg. frequency of field visits for CC monitoring	Conservation intervention map at property scale? (scale)	Conservation interventions mapped at property scale
Agua Somos	1-2 times per month	No, only a map of properties with contracts and priority areas for intervention exists (1:4,000)	-
ASOBOLO	Once per month	Yes, updated with information from field visits	Riparian buffer area, protected and recovering forest patches, tree planting polygons, conservation strips
CuencaVerde	Once per month	Yes, updated with information from field visits	Riparian buffer area, protected and recovering forest patches
CSAH Cali	2 times per month	Yes, updated with information from field visits (1:2,000)	Riparian buffer area, protected and recovering forest patches, agroforestry systems, live fences, conservation strips, tree planting, biodigesters, silvopastoral systems, springs, local roads, crop and pasture land, rivers
Conservador das Águas	Every 2 months	Yes, updated with information from field visits (1:2,500)	Forest, riparian vegetation and other protected areas according to Brazilian Forest Law, crop and pasture land, water bodies, farm facilities, local roads
Projeto Piloto PCJ	2 times per year	Yes	Riparian buffer area
ProdutorES de Água	Once per year	Yes, but only forest already present; updated with information from field visits	As there was no intervention for ES improvement, features that were mapped were only forest remnants on each property at the beginning of the project

Land Use and Land Cover (LULC): Categorical LULC maps were used by all seven schemes to define the watershed LULC baseline conditions (Table 4-5). These maps help compare and quantify different classes of land use before and after interventions. In all cases, intermediaries used LULC maps from external sources, mostly from government organizations but also from non-profit research centres. In three cases, the reported map scale was 1:25,000, while one was 1:80,000, and in the remaining cases the intermediaries did not provide this information (Table 4-5). The available LULC maps from the external sources commonly referred to a year different to the one in which the conservation project started. For example in the ASOBOLO case, although interventions started in 2011 in Aguaclara, the available LULC map is from 2005. The map was updated with local community members by visual recognition in the field.

Some of the LULC maps include a differentiation among types of local vegetation, e.g. the one used by Agua Somos, while others divided vegetation in stages of recovery, e.g. the one used by Projeto Piloto PCJ. Cropland categories were also diverse, with some maps detailing types of crop, e.g. the one used by ASOBOLO, and others reporting only one category, such as the one used by Conservador das Águas (Table 4-5). The reason for this variability in terms of precision of categories relies on the fact that those LULC maps were produced for other purposes and, therefore, may not be entirely suitable for the purposes of the PWS schemes. The frequency of updates in the LULC map at the watershed scale may indicate how well the links between the observed variability in streamflow and water quality with the actual land use change can be identified. From the seven cases under study, three cases reported 1 update after the baseline map, one case reported a sequence of 3 updates based on field visual observation, while two cases did not report any updates. In the PCJ case, in addition to the use of third part maps from 2003 and 2010, new land cover images were acquired in 2011 for updates.

Table 4-5: Watershed land use and land cover (LULC) baseline and monitoring

Scheme	Baseline map: year, source	Scale of LULC map	LULC map categories for the watershed	Updates in LULC map
Agua Somos	2010, UNAL[(1)]	1:80,000	Shrub, fragmented forest, secondary forest, riparian vegetation, reservoir/lake, mixture of crop and pasture land, paramo, cropland, specific forest types, peat bog	No updates
ASOBOLO	2005, CVC	1:25,000	Natural grassland, coffee, stubble field, permanent crop, infrastructure, semi-permanent crop, transient crop, natural forest, planted forest	1 update in 2016 by visual recognition of changes in the field
CuencaVerde	2007, Antioquia Government	1:25,000	Riparian vegetation, natural dense forest, natural fragmented forest with shrubs, natural fragmented forest with grazed land and crops, paramo and subparamo vegetation	Updates in 2015, 2016, 2017 with aerial images at particular sites of interest
CSAH Cali	2009, DAGMA	1:25,000[(2)]	Mixed forest, urban, pasture, summer pasture, deciduous forest, agriculture land/row crops, agriculture land/close-grown	No updates used by the scheme
Conservador das Águas	2006, Extrema municipality	Not informed	Forest, riparian vegetation and other protected areas according to Brazilian Forest Law, crop and pasture land, water bodies	1 update since first map (using different methodology)
Projeto Piloto PCJ	2003, Instituto Socioambiental	Not informed	Agriculture, sparse human settlement, bare soil, secondary vegetation (two classes), anthropic area, reforestation	1 update in 2010
ProdutorES de Água	2009 SEAMA/ES	Not informed	Riparian vegetation	No updates

Abbreviations: UNAL – Universidad Nacional de Colombia; CVC - Corporación Autónoma Regional del Valle del Cauca; CIPAV – Fundación Centro para la Investigación en Sistemas Sostenibles de Producción Agropecuaria; SEAMA/ES – Secretaria de Estado de Meio Ambiente e Recursos Hídricos do Espírito Santo; [(1)] Source: (Vargas et al., 2013). [(2)] Source: Fondo Patrimonio Natural et al., 2014.

Climate: the studied schemes often rely on climate data, e.g. precipitation, radiation and air temperature, produced by local authorities, such as environmental agencies. The advantage of these datasets is that they can constitute long-term historic series that allow a better understanding of the regional climate patterns. Climate data from these sources are either used for describing the environmental conditions of the watershed, e.g. Agua Somos and Cuenca Verde, or for hydrologic modelling, e.g. ASOBOLO and CSAH Cali. ProdutorES was the only case that did not report the use of climate data. The number and density of climatological stations in the project areas varied. Official climate data cover large areas, but are usually poorly distributed and scarce, and, therefore, typically insufficient for representing hydrologic processes in small watersheds. In addition, the monitoring frequency may not be enough to detect meteorological events of local importance, particularly in tropical watersheds where storms can be fast but voluminous. In response to these shortcomings, some of the schemes started a collaborative effort to install hydroclimatological stations in the watersheds under intervention. Some of these stations register all important variables such as radiation, precipitation, wind direction and intensity, air pressure, humidity, and air temperature, while others may be of a compact type, measuring a reduced set of variables. Pluviometers alone are also used. ASOBOLO, for example, now counts 1 complete station installed in the Aguaclara watershed, 3 compact climate stations and 8 pluviometers managed by CENICAÑA (Hoyos-Villada et al., 2016; Lima et al., 2017). In the Conservador das Águas project, 5 pluviometers were installed in 2008.

River discharge: As with climate data, streamflow datasets available from official organizations, such as environmental agencies, are usually not in a suitable resolution to characterize local processes in a watershed. Therefore, a complementary local monitoring network is often needed to observe potential conservation impacts. Among the cases studied, three have installed additional instruments for streamflow monitoring: ASOBOLO, Conservador das Águas, and Projeto Piloto PCJ; Agua Somos performed river discharge measurements during field campaigns (Table 4-6). In the cases of Conservador das Águas and Projeto Piloto PCJ, the national water agency (ANA) as a project partner, the state university (USP) and NGOs (e.g. TNC) are supporting hydrological monitoring. In the ASOBOLO case, 4 automated water level stations were installed at the end of 2013. They also use data from one station managed by CVC. The Projeto Piloto PCJ installed 6 monitoring points in 2014 and 11 other points were part of field campaigns for discharge measurements. Stations were installed in the form of cemented weirs that allow more precise measurements compared to natural cross-sections. Agua Somos hired consultants to measure point river discharge at 3 points, upstream, downstream and close to conservation intervention sites. CuencaVerde did not report river discharge data produced by themselves, but is waiting for data delivery from third parties, such as the local water supply company. ProdutorES did not report any streamflow monitoring or use of secondary data.

Water quality: All PWS cases reported monitoring of water quality parameters, either through external consultancy, e.g. Agua Somos, or through technical collaboration, e.g. ASOBOLO Table 4-7), or directly by the PWS technicians, e.g. CuencaVerde. The latter developed its own monitoring protocol with the support of the local water supply company in order to sample water close to the intervention sites; ProdutorES is in charge of its own water quality monitoring performed by IEMA/SEAMA. CSAH Cali reported water quality data obtained from CVC for baseline and modelling studies, and a monitoring protocol consisting of biologic, biophysical, and chemical indicators of water quality. In terms of frequency, the projects Conservador das Águas and Projeto Piloto PCJ are the ones with the most frequent measurements, the former measuring once per month and the latter every 2 months. In the Colombian cases, most of the water quality parameters are measured twice per year.

Control cases: The literature on impact evaluation has pointed out that in order to assess additionality, it is important to exclude potential explanations for the observed changes that are not related to the scheme (Boerner et al., 2017; Ferraro, 2009; Gertler et al., 2011; Wunder, 2005). While assessing conservation strategies in watersheds, hydrologists usually propose monitoring a neighbouring catchment without conservation interventions for comparison (e.g. Higgins and Zimmerling, 2013). The adoption of this strategy was reported in two of the seven cases: ASOBOLO and Projeto Piloto PCJ.

Table 4-6: River discharge (RD) baseline and monitoring

Scheme	Entity in charge of RD monitoring data used by the scheme	RD monitoring method	Nearest distance from monitoring point to conservation sites (m)	Frequency of RD monitoring	Number of RD monitoring points	Smallest Upstream area (ha)	Baseline year of local RD monitoring	Quality of the cross section of RD monitoring points
Agua Somos	Patrimonio Natural	Propeller current meter; channel cross section	Not informed	2 per year	3	Not informed	2016	Natural river bed with coarse and fine sediments
ASOBOLO	CENICAÑA	Automated stage recording; Rating curve	5 m from property with intervention	15 min	4	108	2014	Rectangular cement weir
Cuenca Verde	EPM	Stage recording; Rating curve	Not informed	not informed	1	17,000	1982	Not informed
CSAH Cali	CVC	Automated stage recording; Rating curve	Not informed	Daily	2	Not informed	1946 and 1969	Rectangular cement weir
Conservador das Águas	(a) EESC/USP* (b) ANA	Stage recording; Rating curve	Not informed	Daily	(a) 7 (b) 2	Not informed	(a) 2012 to 2014 (b) 2008	Rectangular cement weir
Projeto Piloto PCJ*	EESC/USP	Automated stage recording and Rating curve (6 points); Propeller current meter (11 points)	Inside property with intervention	5 min to 1 hour	7	201‡	2012 to 2014	Rectangular cement weir
ProdutorES de Água	-	-	-	-	-	-	-	-

Abbreviation: ANA – National Water Agency, Brazil. EESC/USP – Escola de Engenharia de São Carlos/Universidade de São Paulo; WWF – World Wildlife Foundation; CPRM – Geological Service of Brazil. * Information obtained from Taffarello et al. (2016, 2013). ‡This refers to the smallest upstream area among catchments with intervention; the smallest upstream area among all monitored ones is a control catchment of 66 ha.

Table 4-7: Water quality (WQ) monitoring

Scheme	Entity in charge of WQ monitoring data used by the scheme	WQ parameters monitored	Approx. nearest distance from monitoring point to conservation sites (m)	Frequency of WQ monitoring	Number of WQ monitoring points, year	Baseline year
Agua Somos	Patrimonio Natural	TEMP, DO, BOD, COD, pH, EC, TDS, TS, AC, TOC, color, TH, PHO, NIT, pesticides, TSS, turbidity, COL, TS	Inside property with intervention	2 times per year	3 (as of 2016)	2012 (external sources), 2016 (own source) (1)
ASOBOLO	CENICAÑA	TEMP, DO, BOD, COD, pH, EC, TDS, TS, TSS, TH, AC, PHO, NIT, COL, TSED, NO_2^-, NO_3^-, turbidity	5	Turbidity: every 15 min. Others: 2 times per year	4 (as of 2016)	2014 (own source)
CuencaVerde	CuencaVerde	TEMP, EC, TSS, turbidity, TH, TDS, AC, PHO, COD, pH, DO, BOD, NIT, COL	Inside property with intervention	2 times per year	11 (as of 2016)	2014 (2) (own source)
CSAH Cali	Acueducto San Antonio – EMCALI CVC	TEMP, EC, TH, TSS, turbidity, AC, colour, PHO, COD, pH, DO, BOD, NIT, NO_2^-, NO_3^-, NH_3, COL, Mn^{+2}, Mn^{+4}, Cl^-, Na^+, Fe^{+2}, Fe^{+3}	1000	Turbidity and TSS: monthly. Others: 2 times per year	Turbidity: 5 Others: 7	Turbidity: 2010. Others: 1996 (external sources) (3)
Conservador das Águas	ANA	TEMP, EC, DO, turbidity, pH	Unknown	Monthly	7	2008
Projeto Piloto PCJ*	ANA, TNC, WWF, EESC/USP	Turbidity, TEMP, EC, TSS, TDS, PHO, COD, pH, DO, BOD, NIT, NO_2^-, NO_3^-, NH_3, COL	Inside property with intervention	Every 2 months	6	2013/2014 (own sources)
ProdutorES de Água	IEMA/SEAMA	Turbidity, EC, pH	Unknown	Not informed	11	Not informed

Abbreviations: TEMP – temperature, DO – dissolved oxygen, BOD – biochemical oxygen demand, COD – chemical oxygen demand, DOM – dissolved organic matter, TS – total solids, TDS – total dissolved solids, TSS – total suspended solids, TSED – total sedimentable solids, TH – total hardness, EC – electrical conductivity, AC – alkalinity, PHO – total phosphorus, NIT – total nitrogen, NO_2^- – nitrite, NO_3^- –nitrate, COL – coliforms, Mn^{+2}, Mn^{+4} – manganese, Cl^- – chlorine, Na^+ – sodium, Fe^{+2}, Fe^{+3}– iron.

* Information obtained from (Taffarello et al., 2016b, 2016c, 2013). The project ended in 2014. (1) Patrimonio Natural hired external consultants to evaluate WQ in 2016, however, they already had WQ data from a study delivered by UNAL (Universidad Nacional de Colombia) in 2013 (Vargas et al., 2013), and a report on WQ for Chisacá River in 2014 (Empresa de Acueducto y Alcantarillado de Bogotá and Pontificia Universidad Javeriana, 2014). It is not clear if the sampling points correspond to those of 2016. Here we consider 2016 as baseline because it refers exclusively to sampling made for the evaluation of the scheme near the intervention sites. (2) CuencaVerde collected WQ information from previous studies for the area with data from 2007, however, monitoring near conservation sites started in 2015 (CuencaVerde, 2015). (3)Baseline water quality data are available from the regional environmental authority, CVC, Source: (Baena-Álvarez, 2007).

4.3.2 Collaborations for impact evaluation

Interviewed representatives from all projects, except ProdutorES, declared a significant network of technical and scientific collaborations for the assessment of project impacts: with environmental authorities for the production of primary data or obtaining secondary data; with universities and research centres for research purposes; with NGOs that provide technical assistance and funds from international cooperation. Few companies participating as payers support impact evaluation directly either by providing environmental data or performing part of the monitoring.

The collaborations with **environmental authorities** are clear in: (1) Agua Somos obtains GIS data from the District Secretary of Environment, SDA, which is one of the scheme's payers; (2) ASOBOLO is supported by the regional environmental authority, CVC, from which they obtain a considerable amount of environmental data; (3) CuencaVerde collaborates with two regional environmental authorities, CORNARE as an associated member, and CORANTIOQUIA, from which they obtain environmental data; (4) CSAH Cali obtains hydroclimatologic and water quality data from CVC; (5, 6) Conservador das Águas and Projeto Piloto PCJ get strong monitoring support from ANA.

Several schemes have collaborations with – or commissioned studies from – **research centres and universities** for the production of primary environmental data: (1) Agua Somos obtained research studies on biodiversity and ecosystem restoration guidelines from the local public university, UNAL (Vargas et al., 2013), and on priority areas for landscape conservation from Instituto Humboldt Colombia (2014); (2) ASOBOLO obtained a hydrologic modelling study through TNC from consultancy work done by CIAT (Uribe et al., 2009); ASOBOLO has a strong partnership with the private research centre CENICAÑA (Hoyos-Villada et al., 2016; Lima et al., 2017); (3) CSAH Cali relies on an important partnership with the regional research centre CIPAV (Fondo Patrimonio Natural et al., 2014; Fundación CIPAV, 2011; Galindo, 2016), which performed several studies on the land use, vegetation cover, biodiversity, water microorganisms, and monitoring of contract compliance; (4) Conservador das Águas has a partnership for hydroclimatologic research with the state university, USP; (5) Projeto Piloto PCJ has collaborations with the state engineering school, EESC/USP.

In one case, CuencaVerde, a technical collaboration ensued with one of the **companies** belonging to the payers group. A local dairy production cooperative conducted the water quality analysis in their private laboratories. Other cases found the technical collaboration with payers harder. For instance, none of the Colombian schemes has reported obtaining streamflow data from the water supply companies that act as payers in these schemes, although water supply companies usually have the most detailed data on streamflow and water quality at the local level. Some of them reported that due to "sensitivity issues" related to data protection there is a long bureaucratic path to get access to this type of data which so far they were unable to follow.

Three international **NGOs** have been present in one or more schemes: TNC, Fundación Patrimonio Natural, and WWF. Through the *Latin American Water Funds Partnership*, LAWFP (The Nature Conservancy et al., 2017), TNC has been supporting the schemes Agua Somos, ASOBOLO, CuencaVerde, Conservador das Águas, and projeto piloto PCJ (Bremer et al., 2016b). This support has been in the form of technical assistance to develop monitoring protocols, technical exchange and learning among practitioners, and by prospecting funds for monitoring systems and technical studies (Bremer et al., 2016c; Higgins and Zimmerling, 2013). The LAWFP is connected with American universities and research centers through the Natural Capital Project, NatCap (Latin America Conservation Council; The Nature Conservancy, 2015). The NatCap team develops models and tools to support the water funds. Fundación Patrimonio Natural manages Agua Somos and develops technical studies for the case. Patrimonio Natural has also supported CSAH Cali with funding and assistance for technical studies and monitoring in partnership with CIPAV (Fondo Patrimonio Natural et al., 2014).

4.4 Discussion

4.4.1 Institutional factors driving the efforts to demonstrate additionality

PWS schemes are founded on certain assumptions about the interaction between LULC and water resources conditions (Kosoy et al., 2007; Ponette-González et al., 2014; Porras et al., 2008). These assumptions have been extensively debated among environmental scientists, particularly among hydrologists (Alila et al., 2009; Bruijnzeel, 1990, 1989, Calder, 2004, 2002; van Dijk et al., 2009). There remains considerable uncertainty about how certain types of changes in land use may interfere with water quality and hydrological processes such as infiltration, evapotranspiration, runoff, and soil erosion. In addition, limited environmental monitoring, a common situation in developing countries (e.g. Porras et al., 2013), makes it difficult to establish clear causal links between land use and water resources conditions (Barnaud and Antona, 2014; Kosoy et al., 2007; Lele, 2009; Lima et al., 2017; Muradian et al., 2010). Hence, the call for impact evidence of PWS schemes has intensified in recent years (Baylis et al., 2015; Boerner et al., 2017; Carpenter et al., 2009; Naeem et al., 2015).

The schemes studied here are responding to this increasing demand for impact evaluation and institutional settings may partially explain these recent efforts. Almost all schemes are gradually implementing monitoring systems and control cases. ProdutorES de Água is an exception in that it adopted very little monitoring because the goal was not to improve ES per se but rather to reward farmers that had already preserved forest on their land. The collaborations between intermediaries and local research centres in the design, implementation and testing of monitoring and evaluation systems are indicators of the increasing concern with impact evidence. The benefits are mutual; intermediaries gain technical-scientific capacity while researchers gain access to empirical case studies.

No funding was actually directed to impact evaluation when most of the studied schemes were set up because priorities were directed to political mobilization, negotiation, and implementation of the projects in the early phases. Along with the turn to evidence of additionality, however, more funding for assessing the impact of the schemes on the target ES has started to emerge. For example, USAID has funded a sophisticated monitoring system installed in the Aguaclara watershed were ASOBOLO works (Hoyos-Villada et al., 2016; Lima et al., 2017).

Another oversight of the early phases of PWS schemes is more detrimental; in the majority of the schemes studied here, no baselines of environmental variables (apart from land use and cover) and no monitoring protocols were established at beginning of the schemes (as also noted by Ponette-González et al., 2014), which is now severely compromising evidence of additionality. Our empirical material suggests that PWS proponents and managers begun their activities relying merely on assumptions that positively associate forest cover with more water, flood regulation, better water quality, and less erosion and sediments (Kosoy et al., 2007; Ponette-González et al., 2014). Only in some cases were previous environmental studies available from other projects of the stakeholders involved. Younger schemes such as CuencaVerde and CSAH Cali, undertook greater efforts to gather secondary information about the baseline environmental conditions of the watersheds. In the other Colombian cases, ASOBOLO and Agua Somos, this was not an early priority, although it came later incentivized by TNC. In the Brazilian cases, too, ES baseline conditions were not assessed.

All schemes studied emerged from very specific institutional circumstances, responding to demands from a diverse set of actors, interests and influences. Several schemes were born in a "window of opportunity" opened by large and flash funding available for the PES approach. A clear example is the CSAH Cali, in which the Dutch funding, together with a five-year timeline, was the main driving force behind the scheme. Another case is the ProdutorES de Água, in which a strong interest by local politicians enabled the implementation of the project. This project is the only case without emphasis on additionality from the beginning and at the same time no dependence on international funding that required impact evaluation. The ProdutorES case was born from a mix of local political willingness and technical interest from government officials, and hence there was no need to respond to external demands of additionality evidence or to conform to certain efficiency indicators.

Most of the schemes, apart from CSAH Cali, are supported by TNC (either since the beginning or later), one of the largest international conservation NGOs. TNC has extensively promoted the water fund model and is gaining large acceptance in Latin American countries (Bremer et al., 2016b; Calvache et al., 2012; Goldman-Benner et al., 2012; R. L. Goldman et al., 2010). Other water fund partners are development and cooperation agencies, such as IADB and GEF, that have been funding PES schemes worldwide. TNC presents itself as a science-based NGO, and promoting monitoring best-practices to demonstrate additionality fits with this agenda. The concern with providing evidence in order to keep trust among stakeholders and secure payers is frequently mentioned in TNC manuals and reports (Bremer et al., 2016c; Calvache et al., 2012; Higgins and Zimmerling, 2013), and monitoring impacts was one of the core topics of the latest international conference of the Latin-American Water Funds Partnership held in Bogotá in 2016.

Another important driver for raising evidence on additionality has been the World Bank, funder of a large number of PES schemes worldwide (DNP et al., 2013; Engel et al., 2008; Pagiola, 2008; Pagiola et al., 2016, 2013; Pagiola and Arcenas, 2013). The World Bank has promoted impact evaluation and demanded it from the projects it supports, not only in the conservation sector, but in development programmes as well (Gertler et al., 2011).

4.4.2 Constraints faced by PWS intermediaries to demonstrate additionality

Despite the favourable context towards impact evaluation of conservation projects with increasing international incentives, demonstrating additionality remains fraught with uncertainties (Lima et al., 2017). In their quest for impact evidence, intermediaries are struggling to adjust their *in situ* measurements to the spatial scale and frequency that will allow detecting the conservation impacts on water resources and exclude other potential explanations. With very short hydrologic baseline data, it may take years to understand what constitutes natural variability of the hydrological processes of the watershed and what is attributable to interventions. Even with the correct technical apparatus for detecting hydrologic change, it may take several years to see any substantial effect of conservation efforts due to the long residence times of water and pollutants (Lima et al., 2017). Moreover, if the land use and land cover dynamics are not characterized for the entire watershed, it will be hard to detect conservation impacts in the presence of other confounding factors associated with land use on properties that are not part of the PWS agreements. It is also not always possible to find catchments suitable to serve as control cases due to biophysical features that are unique among catchments (Beven, 2000).

The measurement challenge of providing evidence of additionality is exacerbated by a series of practical constraints, including lack of funding. Schemes based on voluntary engagement are always subject to funding discontinuity (e.g. reported by ASOBOLO, Lima et al., 2017), and this may compromise the possibilities of long-term continuous monitoring. In the Colombian cases, which are managed by civil associations or NGOs, interviewees reported that companies funding their schemes are usually not interested in paying for environmental monitoring or research, but rather request the funds to be spent directly on conservation practices. In the Brazilian cases, interviewees from the Projeto Piloto PCJ declared that there is no funding for technical staff dedicated exclusively to monitoring and impact assessment. The strategy applied in this case and in the Conservador das Águas is to establish partnerships with local universities and research centres so that researchers and students conduct data collection/analysis that is useful for the project.

Problems with data sharing, even among collaborators, were regularly reported in the interviews. Interviewees from the Colombian cases reported what they called "institutional jealousy", meaning that although organizations cooperate, they may compete at the same time. For instance, partners may share reports but not the original raw data. In other cases, data may be retained until scientific publications are completed in order to prevent opportunistic behaviour from alleged competitors (Lima et al., 2017). A case in point are the complicated data sharing agreements that the water supply companies in Colombia set up in order to share streamflow data.

Access to official data is particularly problematic in Colombia, where the national law on data transparency and access is relatively recent, dating back to 2014 (Colombian Law n. 1712). Until recently, data access was difficult for those working with conservation, as reported by interviewees. Even with the new law, depending on the source, the application process is complicated and the data may take more than a month to arrive. As the regional agencies have different performance levels, some have accessible websites that provide data, while others have not. Notable exceptions are the national agencies in charge of cartographic data (Instituto Geográfico Agustín Codazzi, IGAC) and environmental data (Instituto de Hidrología, Meteorología y Estudios Ambientales, IDEAM) which have accessible online databases. In Brazil, data access can be slightly easier. The law on transparency and access to official data (Federal Law n. 12527) was launched in 2011 and there is already a well-established online platform for data requests with procedures clearly explained. Even before 2011, access to hydrologic data was already straight forward; the national water agency has an online platform with the updated database of streamflow and river morphology for the entire country. Similarly, the agency in charge of national statistics and geographic data (Instituto Brasileiro de Geografia e Estatística, IBGE) provides updated data online in accessible formats.

In both countries, baseline data for conservation projects in local watersheds may be the greatest challenge. Although there is a large network of streamflow, water quality and climatologic stations managed by regional and national agencies, this information is seldom collected at the small scales required for providing a baseline for conservation projects (Lima et al., 2017). Technicians working in all the schemes studied, apart from ProdutorES which does not monitor river discharge, reported having a hard time describing the streamflow dynamics prior to the schemes' operation. In most cases, they needed to rely on regional studies to describe the behaviour of the watersheds they were working in by way of down-scaling until they had the chance to set their own monitoring system. The errors in down-scaling due to the loss of important small-scale heterogeneity are severe. When it comes to the land use and land cover baseline for the watersheds, the greatest challenge is not data availability, as several remote sensing products are now available for public use at no or reduced cost, but rather technical capacity and funding to develop a good GIS database and protocols for image processing, classification and comparison. If categorical maps are not standardized in terms of categories they may allow ex-ante and ex-post comparison. A lack of knowledge on GIS best practices is also very common among conservation initiatives in Latin America and even among researchers, leading to disorganized collections of maps without proper metadata information that would allow reuse of these data.

Lack of technical capacity for environmental monitoring is another constraint reported in the case studies. While some schemes have technicians from government agencies actively engaged, e.g. from ANA in Conservador das Águas and PCJ, or have hired environmental professionals, e.g. CuencaVerde, others rely on the support of partners, such as ASOBOLO with CENICAÑA and CSAH Cali with CIPAV, and some need to pay external consultancies for punctual monitoring, e.g. Agua Somos. Lack of technical capacity also constrains the quality of the products, such as geographic information system (GIS) products. Because it is often hard to have a GIS professional hired full-time to support PWS schemes, the intermediaries rely on maps produced for other purposes by their partners and, therefore, end up using GIS data and products that are neither entirely suitable to represent the geographic features that they need, nor completely updated.

The challenges are many. From the unsettled scientific knowledge about the links between land use and water resources (Lele, 2009; Ponette-González et al., 2014), to the practical constraints, such as high transaction costs (McCann, 2013), and limited budget and technical capacity for monitoring (Lima et al., 2017; Muradian et al., 2010), PWS schemes have a long road towards additionality evidence, if they ever get there.

4.5 Conclusion

PWS schemes are responding to an increasing international demand for impact evaluation on the conservation sector. Almost all schemes explored in this study are gradually implementing monitoring systems. The collaborations between intermediaries and local research centres in the design, implementation and testing of monitoring and evaluation systems are indicators of the increasing concern with impact evidence. However, in the majority of the schemes, no baselines of important environmental variables and no monitoring protocols were established at beginning, which is now severely compromising evidence of additionality. The measurement challenge is exacerbated by a series of practical constraints, including lack of continuous funding due to the voluntary character of such schemes. Problems with data sharing, even among collaborators are frequent. In Latin America in general, baseline data for conservation projects in local watersheds may be the greatest challenge. Assessing additionality as promoted in the literature, i.e. clearly defining unequivocal effects of interventions has been arguably infeasible in most cases so far.

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5 Will PES schemes survive in the long-term without evidence of their effectiveness? Exploring four water-related cases in Colombia

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ABSTRACT

The idea of securing ecosystem service (ES) provision through payments for ecosystem services (PES) has been present in practical discourses from intermediaries towards potential payers. However, demonstrating that PES can actually achieve the intended goals is a hard task due to the complexity and uncertainty that characterize the systems involved. Therefore, it is expected that, in face of high uncertainty, payers would leave the projects if effectiveness cannot be demonstrated and, therefore, providers would not keep their conservation practices if no money remains available. Consequently, it is expected that PES proponents would do their best to prove ES delivery. Here we explore these hypotheses in the field using data collected from water-related PES schemes in Colombia funded by public-private partnerships. Our results show that payers have additional motivations for engaging and most of them would not leave the scheme if effectiveness is not demonstrated. Still, they require indicators from intermediaries, mostly related to the activities performed. Most of the providers declared that they would have engaged in the scheme even without economic incentives because they are concerned in protecting water resources for themselves. Intermediaries are the ones mostly concerned in presenting evidence of PES additionality for many reasons.

5.1 Introduction

The Ecosystem Services (ES) concept has gained strong rhetorical power (Kull et al., 2015) and are shaping practices among conservationists (Fisher and Brown, 2014). Non-government organizations and development agencies are increasingly working with instruments derived from the ES approach such as Payments for Ecosystem Services (PES) schemes (Ezzine-De-Blas et al., 2016; Grima et al., 2016).

Funding from private and public companies has been strategic for several conservation schemes in Latin America. In order to communicate better with the business sector so as to attract more funding conservation organizations have been adapting their discourses towards a more business-like language with the utilitarian arguments of the ES approach (Fisher and Brown, 2014). In doing so, several of them have ended up using business jargons, e.g. investment portfolio, business case, performance indicator, return-on-investment (e.g. Boyd et al., 2012; Hanson et al., 2012, 2011). They also have been putting strong emphasis on cost comparison of conservation strategies versus conventional solutions for the same ends (e.g. 'green infrastructure' versus 'gray infrastructure', see Bennett and Ruef, 2016; Calvache et al., 2012; Postel and Thompson, 2005). Recent debates among practitioners also suggest that ES payers are increasingly inclined to adopt performance-based payments creating a need for PES impact evidence (Gammie, 2016). The growing use of business-like language on ES approaches is frequently supported by the use of predictive numbers related to ES goals derived from modelling (e.g. Crossman et al., 2013; Quintero et al., 2009; Ruckelshaus et al., 2015; Tallis and Polasky, 2009).

The idea of securing ES provision is not only strongly present in the literature (e.g. Wunder, 2005), but also in practical discourses towards potential payers; even though being deeply criticized in the literature because of the implied simplification of social-ecological systems (Kosoy and Corbera, 2010; Muradian et al., 2010; Norgaard, 2010) and the practical difficulty to prove service delivery (Carpenter et al., 2009; Lele, 2009; Palmer and Filoso, 2009; Ponette-González et al., 2014). This way of approaching and practicing conservation implies a control over a service being sold which may not actually be secured, especially in the case of water-related PES schemes (Barnaud and Antona, 2014; Kosoy and Corbera, 2010). So far, incomplete knowledge about the processes behind water-related services together with a lack of monitoring best practices in most cases have hindered the evidence of PES impacts (Bohensky and Lynam, 2005; Carpenter et al., 2009; Lele, 2009; Norgaard, 2010; Palmer and Filoso, 2009).

Discourses based strongly on economic aspects disregarding scientific uncertainty underlying ES provision can lead to unrealistic expectations from actors involved in these schemes. If expectations are not fulfilled those schemes may not endure. Under this perspective, a question remains empirically under-explored: will PES schemes survive in the long-term if no evidence of their impact on the target ES is achieved? A first hypothesis would be that if uncertainty is large, practitioners cannot prove PES effectiveness through impact evidence, and payers are only looking for returns in terms of ES, then they would leave the PES scheme. This hypothesis is sustained by Wunder (2005, p. 3), "the less realistic the scientific basis of a PES scheme, the more exposed it is to the risk of buyers questioning its rationale and abandoning payments". Consequently, assuming that landowners are acting solely as "providers" of a service based on a rational and utility-maximizer perspective, they would abandon the scheme too as no money is left to pay them. At the same time, PES intermediaries, e.g. non-government organizations (NGOs), would lose credibility due to their "unfulfilled promises" of ES delivery and would have their reputation at risk (Fisher and Brown, 2014). This hypothesis implies that ES monitoring, evaluation and reporting are strongly needed to produce the right evidence to keep payers and providers on board (Naeem et al., 2015).

However, if additional motivations, environmental perceptions and values are in place, then the assumptions made in theory regarding expectations from each actor and the importance of evidence of ES delivery may be questioned. In fact, recent studies have proposed that intrinsic motivations, e.g. a desire to "care for the land" (Méndez-López et al., 2015, p. 695), or the "warm-glow effect" (Andreoni, 1990), can play a strong role on conservation schemes engagement by land owners (Ezzine-de-blas et al., 2015; Kits et al., 2014; Kosoy et al., 2008; Zanella et al., 2014). In the same way, a mixture of motivations, e.g. green marketing or to maintain reputational capital, may be in place when corporate leaders decide to invest in environmental programs (Babiak and Trendafilova, 2011; Chin et al., 2013; Ditlev-simonsen and Midttun, 2011; Hemingway and Maclagan, 2004). Therefore, these schemes may last even without evidence of achieved ES goals.

In this paper, we explore motivations and expectations of actors involved in PES schemes in order to assess the importance of impact evidence in the scheme long-term durability. We compare the perspectives of three groups involved in four water-related PES schemes in Colombia: intermediaries, landowners (providers), and major donors (payers). We focus our questions on whether additional motivations from payers and providers would play a role in their engagement and permanence in the scheme; if payers demand evidence of PES impacts on ES provision; and if intermediaries feel in the need to provide evidence of achievements of ES goals through monitoring and reporting.

5.2 Methods

5.2.1 Study sites

This study was conducted in four water-related PES schemes (here also called payments for watershed services - PWS) in Colombia:

1) "Agua Somos" (Chisacá and Mugroso river watersheds - tributaries of Tunjuelo river; located in Usme, Bogotá D.C.);
2) Asociación de Usuarios de Agua del Río Bolo – "ASOBOLO" (Aguaclara river watershed - tributary of Bolo River; located in Pradera and Palmira municipalities, Valle del Cauca Department);
3) Compensación por Servicios Ambientales Hidricos Cuenca del Río Cali - "CSAH Cali" (Felidia and Pichindé rivers watersheds – tributaries of Cali River; located in Cali municipality, Valle del Cauca Department);

4) "Cuenca Verde" (Chico river watershed - tributary of Riogrande River; located in Belmira municipality, Antioquia) (Figure 1-1).

We conducted a preliminary fieldwork of two weeks in January 2015, followed by a 6-months fieldwork from January to June 2016. The study was based on semi-structured interviews, questionnaires, participant observation, and literature review of reports and related documents from the organizations managing the schemes. We followed intermediaries in their daily work in the field and office, and attended a major conference with the presence of PWS managers and payers from three of the studied schemes (June 13th to 17th, 2016, Bogotá D.C.). Interviews and questionnaires were applied to three groups: providers, intermediaries, and major payers. Here we consider PWS intermediaries as "actors who take on roles that connect and facilitate transactions between buyers and sellers" (Huber-Stearns et al., 2013, p. 105). Providers in these schemes are usually small landowners living in the upstream area of the watersheds; intermediaries are non-government organizations; and payers are mostly private companies, public companies and environmental authorities.

The PWS conservation activities undertaken in the watersheds through the schemes under study started quite recently; from 2011 onwards (Table 5-1). In all four schemes, conservation practices are mostly concentrated in river and spring fencing for protection against the cattle at the upstream lands (Table 5-2). Some of the initiatives (e.g. by ASOBOLO) also include implementation of live fences and agrosilvopastoral systems, cattle rotational grazing, and other farm practices to reduce the impact of cattle on the soil of mountainous areas. In order to set those practices, the intermediaries establish voluntary conservation agreements with each upstream landowner, the providers. The agreements include payments to the providers that are usually in-kind, including technical assistance in the farm, materials for the conservation practices, and farm infrastructure improvement. Among the studied cases, CSAH Cali is the only program that pays in cash.

Table 5-1: Description of the four PWS schemes: literature references, watershed location, intermediaries involved, major payers, year in which conservation interventions started, and number of contracts signed up to June, 2016 (only in the referred watershed).

Scheme / References	Watershed, Department	Partnership Programs	Intermediary (Catalysts)	Intermediary (Operator)	Major payers	Year	# of contracts in this watershed
Agua Somos (Goldman-Benner et al., 2012)	Chisacá and Mugroso Rivers, tributary of Tunjuelo River, Dept of Cundinamarca	Latin-American Alliance for Water Funds	TNC	Fundación Patrimonio Natural	TNC, EAAB, SDA, Bavaria/ SabMiller§, Coca-Cola/ FEMSA§	2013	25 (as of February 2016)
ASOBOLO (Moreno-Padilla, 2016; Munoz Escobar et al., 2013)	Aguaclara river, tributary of Bolo River, Dept of Valle del Cauca	Latin-American Alliance for Water Funds; Conservation Incentives	ASOBOLO, ASOCAÑA	ASOBOLO	ASOCAÑA, CVC, Syngenta§, RioPaila§ y Castilla, Mayagüez§	2011 *	56 (as of June 2016)
Cuenca Verde (Gómez-Ochoa, 2016)	Chico River, tributary of Riogrande Reservoir, Dept of Antioquia	Latin-American Alliance for Water Funds	TNC, EPM	Cuenca Verde	EPM§, Postobon§, Nutresa§, Argos§, AMVA, CORNARE	2015	22 (as of June 2016)
CSAH Cali (Fondo Patrimonio Natural et al., 2014)	Felidia and Pinchindé rivers, tributaries of Cali River, Dept of Valle del Cauca	Conservation Incentives	Fundación Patrimonio Natural	AcuaCali.co	The Netherlands government, CVC, EMCali, ASOCAÑA	2013	46 (as of June 2016)

Table abbreviations: AMVA – Área Metropolitana del Valle de Aburrá; ASOCAÑA - Asociación de Cultivadores de Caña de Azúcar de Colombia; ASOBOLO – Asociación de Usuarios de las Aguas Superficiales y Subterráneas de la Cuenca del Río Bolo; CORNARE – Corporación Autónoma Regional de las Cuencas de los Ríos Negro y Nare; CVC - Corporación Autónoma Regional del Valle del Cauca; PN - Fundación Patrimonio Natural; EAAB – Empresa de Acueducto, Alcantarillado y Aseo de Bogotá; EMCali – Empresas Municipales de Cali; EPM – Empresas Públicas de Medellín; TNC - The Nature Conservancy; SDA - Secretaria Distrital de Ambiente; *Refers to the year in which activities started in Aguaclara watershed only. ASOBOLO itself was launched in 1993 and started working in other regions first. §Those companies are among the 100 biggest industry companies in Colombia.

Table 5-2: Target ES, activities performed in the field, type of payment and payments for each PWS scheme.

Scheme	Watershed area	Target ES	Conservation practices performed	Type of Payment	Payments already performed
Agua Somos	Chisacá and Mugroso (8,245 ha)*	Water quality and provision, sediment retention	River fencing, tree planting, cattle rotational grazing systems.	In-kind	Energy saving wood stove, cattle drinking fountains, materials for fences, seedlings
ASOBOLO	Aguaclara (11,141 ha)†	Water flow regulation, sediment retention	River fencing, springs protection, tree planting, forest protection, farm septic tanks, agrosilvopastoral systems, cattle rotational grazing systems, farm live fences.	In-kind	Material for fences, seedlings, septic tanks, financial support for implementing forest reserves, community vegetable gardens, environmental education in schools, capacity building with local associations, technical assistance
Cuenca Verde	Chico (17,172 ha)‡	Water quality	River fencing, forest protection, springs protection, forest restoration, tree planting.	In-kind	Cattle drinking fountains, materials for fences, bridges for cattle, seedlings
CSAH Cali	Felidia (6,635 ha)§ Pichindé (5,272 ha)§	Water quality and provision, sediment retention	River fencing, forest protection, springs protection.	Cash and In-kind	Cash, materials for fences, seedlings, technical assistance

Sources: *Calculated from digital elevation map, upstream Chisacá reservoir; ‡Calculated from digital elevation map, upstream confluence with El Hato stream. †CENICAÑA (Centro de Investigación de la Caña de Azúcar de Colombia) technical staff – personal communication; §Fondo Patrimonio Natural et al., 2014.

5.2.2 Questionnaires and Interviews

Questionnaires were structured in questions that combined open questions, selection of options, ranking, and degree of agreement with some statements (see Appendix I, II and III). For questions regarding degree of agreement a Likert scale of 0 (totally disagree) to 5 (totally agree) was applied. Providers answered their questionnaires in the field. Intermediaries answered their questionnaires either directly in the field or online through an internet link sent to their email address after permission requested in person or by phone. Questionnaires for major payers were applied in the field during the interviews, through teleconference meetings or via email after contact by phone, depending on the availability of the respondents. Semi-structured interviews followed the same topics of the questionnaires in a more flexible approach in order to capture each group's perspectives, differences, opinions, and explanations for their choices.

The structure of the questionnaires started with a session with general information about the respondent and followed topics such as: motivations to participate in the scheme, general expectations based on their own roles and perceptions about the functioning of the scheme and the environmental changes and/or improvements. In addition, the following topics were added according to each respondent group: (1) providers: role of the payment as an incentive for entering the scheme; (2) intermediaries: importance of environmental monitoring, importance of reporting impact evidence, perception of expectations and demands from payers; (3) payers: water-related environmental services of interest, importance of evidence of the achievement of the PES goals for the maintenance of the payment, expectations on impact monitoring and reporting. The initial interviews with the three groups provided the statements used for the agreement questions and the list of motivations of providers and payers. After selecting the motivations from the list with the option of adding new ones, these two groups ranked up to three their most important motivations. We then analyzed all answers in a lumped way.

5.2.3 Characteristics of questionnaires' respondents

Intermediaries group: 25 individuals answered the intermediaries' questionnaire. The questionnaire included intermediaries working not only in the study sites reported here but also in additional PES schemes in Colombia. Three respondents were involved in schemes in Colombia and in other Latin-American countries as part of an international program. Most of the respondents were from NGOs (TNC, PN, and Conservation International - CI). Other respondents included: representatives of local water users' associations (ASOBOLO), representatives of other civil associations (Cuenca Verde), researchers and technicians belonging to local research centers involved in monitoring PES schemes (CENICAÑA - Centro de Investigación de la Caña de Azúcar de Colombia, and CIPAV – Centro para la Investigación en Sistemas Sostenibles de producción agropecuaria), and one representative from a regional environmental authority (Corporación Autónoma Regional del Valle del Cauca, CVC). Table 1-1 summarizes the characteristics of the respondents and their organizations in terms of the roles played in the scheme in which they are involved as intermediaries.

Payer's group: 15 individuals answered the payers' questionnaire. Respondents belonging to the payers group were representatives of several types of organizations/firms, including: two public water supply companies; private companies from the beverage, sugarcane and dairy production sectors, a restaurant, a health clinic, a lawyers firm, an infrastructure company and one service company; and one development organization acting as payer. Respondents reported both in kind a cash payments (Table 1-2). The following types of payments in cash were reported: annual payments (n=6); every 3-6 months (n=3); a one-time payment (n=2); punctual payments through projects in the form of contracts with the intermediaries (n=3); no payments in cash (n=2). Most of them are users of the water from the watershed that they are paying for conservation (Table 1-2).

Providers group: 72 individuals from a total of 149 providers (48%) from the four PES schemes answered the providers' questionnaire. The distribution of respondents in the four schemes was: 12 respondents out of 25 providers from Agua Somos (48%); 30 respondents out of 56 providers from ASOBOLO (54%); 18 respondents out of 22 providers from Cuenca Verde (82%); 12 out of 46 respondents from CSAH Cali (26%) (Table 1-3). Landowners living in farms inherited from relatives are the majority of respondents. A small fraction is not owners but long-term tenants. Most of the respondents have lived their entire life in the region, some of them in the nearby city. They are usually farmers who depend on agricultural production as their main income. Cattle ranching is the most common use of land. Table 1-3 summarizes the main characteristics of the respondents among providers.

5.3 Results

This section presents the results grouped in four core topics: (1) motivations to engage in a PES scheme from payers and providers' perspective; (2) importance of reporting PES impacts from the intermediaries and payers' perspectives; (3) payment upon evidence of PES impacts; (4) environmental indicators of interest.

5.3.1 Motivations to engage in a PES scheme

Payers: ES improvement was selected as one of the motivations by all respondents from the payers group (n=15) (Table 5-3). The second most selected motivation was corporate socio-environmental policy (n=12). Following, corporate image/green marketing and improvement of private-public relations (e.g. with local communities) were selected by 7 respondents each.

Table 5-3: Motivations selection and ranking by payers (absolute values, n, followed by percentage relative to total of answers). First value column refers to the number of times the motivation was selected in the list, including when they did not count among the most important ones. The following value columns refer to the number of times the motivation was ranked as first, second and third most important. Total number of answers is shown in the headings.

id	Motivation	# selections total=15 n (%)	# selected 1st total=15 n (%)	# selected 2nd total=12 n (%)	# selected 3rd total=11 n (%)
A	ES improvement	15 (100)	10 (66.7)	3 (25)	0
B	Corporate socio-environmental policy (CSR)*	12 (80)	4 (26.7)	4 (33.3)	1 (9.1)
C	Corporate image, i.e. green marketing	7 (46.7)	0	0	5 (45.5)
D	Improvement of private-public relations	7 (46.7)	0	0	2 (18.2)
E	Part of the fundamental goals of the organization	3 (20)	1 (6.7)	0	0
F	Part of a mitigation process of our production chain	3 (20)	0	2 (16.7)	1 (9.1)
G	Restoration of areas affected by the organization.	2 (13.3)	0	1 (8.3)	0
H	Sustainability index in stock market	3 (20)	0	0	0
I	Taxes deduction	2 (13.3)	0	1 (8.3)	0
J	Demanded by shareholders	2 (13.3)	0	1 (8.3)	1 (9.1)
K	Environmental compensation required by law	1 (6.7)	0	0	1 (9.1)
L	Environmental investment required by law	1 (6.7)	0	0	0
M	Part of the organization' duties according to the law	1 (6.7)	0	0	0
N	ES was already part of their business tradition	1 (6.7)	0	0	0
O	Facilitate environmental certification	0	0	0	0
P	ES is incorporated in business	0	0	0	0

*Corporate Socio-environmental Policy here is understood as “context-specific organizational actions and policies that take into account stakeholders’ expectations and the triple bottom line of economic, social, and environmental performance (Aguinis, 2012, p. 855).

In sequence, payers’ respondents ranked the first, second, and third most important motivations for them (Table 5-3). The first most important motivations were: ES improvement (n=10), corporate socio-environmental policy (n=4), and ES as part of the goals of the organization (n=1). The second most important motivations were: corporate socio-environmental policy (n=4), ES improvement (n=3), and impact mitigation (n=2). Restoration of areas affected by the organization, taxes deduction and shareholders' demands were selected as second most important motivation by one respondent each. The third most important motivations were: corporate image/green marketing (n=5), improvement of private-public relations (n=2), corporate socio-environmental policy (n=1), mitigation (n=1), compensation required by law (n=1), and shareholders' demand (n=1).

Although not identified as initial motivations by all respondents, the following items were indicated by some of the respondents as non-expected benefits gained after their engagement in PES schemes: better private-public relations, better corporate image, tax deductions, internal sustainability indicators, sustainability index in stock markets, environmental awareness.

Providers: Providers were asked whether they agree with statements connected to their motivations and expectations in participating in the scheme (Table 5-4). When questioned whether they agreed that the scheme would greatly improve productivity conditions in their farm most of them agreed (item A). Almost all providers agreed that they have been always interested in water resources conservation (item B). The following item (Table 5-4, item C) aimed at capturing the compared importance between individual benefit (the farm) and collective (the environment). In this item, opinions were almost uniformly distributed through the scale of agreement. Results from items D and E showed that the majority of providers would have participated in similar conservation schemes even without direct economic benefits for themselves.

On the selection of motivations, more than half of respondents pointed to the expectation of a beneficial effect of the scheme on the water quality/quantity (Table 5-5, item C). Half of respondents indicated a concern with water resources conservation as a motivation for their engagement (item A). Almost half of the respondents reported the scheme's potential for improvement of farm's productivity as one of their motivations (item B). 37% of respondents also reported to have been concerned with conservation even before the proposition of the scheme (item D). Only 6 among 71 providers (8.6%) reported that one of the motivations to engage was that the economic incentives proposed by the intermediaries caught their attention (item K). More common motivations than economic incentive were: enjoying the idea of having a protected forest in the farm (item E); shadow provided by trees for the cattle (item F); and farm's aesthetics (item G). Concerns with water resources conservation figured out as the first most important motivation for 30% of respondents, while improvement of farmers productivity assumed the same position for 25.7%. Expectations with improvement of water quality/quantity assumed the second place as most important motivation for 20% and third place for 27.5% of respondents (Table 5-5).

Table 5-4: Summary of providers' answers to agreement questions.

Id	Agreement Statement	# Answers	Totally Disagree	Partially Disagree	Neither Agree nor Disagree	Partially Agree	Totally Agree
			n (%)				
A	This conservation project will improve a lot the productivity conditions of my farm.	71	3 (4.3)	0	11 (15.7)	25 (35.7)	31 (44.3)
B	I have always been interested in water resources conservation, even before this project.	72	2 (2.8)	0	6 (8.3)	12 (16.7)	52 (72.2)
C	Environmental concerns are important, but it is more important to obtain the benefits of the scheme for my farm.	72	12 (16.7)	8 (11.1)	25 (34.7)	12 (16.7)	15 (20.8)
D	I would participate in any environmental project, even without economic benefits.	71	1 (1.4)	2 (2.8)	5 (7.0)	21 (29.6)	42 (59.2)
E	I would have participated in this scheme, even without having received any economic incentive for that.	72	1 (1.4)	3 (4.2)	5 (6.9)	25 (34.7)	38 (52.8)
F	Detection of the desired effects of the scheme on water quality/quantity will still require some years.	73	1 (1.4)	1 (1.4)	4 (5.5)	11 (15.1)	56 (76.7)

Table 5-5: Ranking of providers' motivations. First number column shows the total number of times the motivation was included among the three most important ones and percentage among respondents. Next number columns report the number of times the motivation was ranked as first, second and third most important.

#	Motivation ("I engaged in the scheme because...")	# ranking selections (N=70)	# selected 1st (N=70)	# selected 2nd (N=70)	# selected 3rd (N=69)
		n (%)			
A	... I began to feel concerned with water resources conservation	35 (50.0)	21 (30.0)	11 (15.7)	3 (4.3)
B	... I thought the scheme would improve my farm's productivity	30 (42.9)	18 (25.7)	6 (8.6)	6 (8.7)
C	... I thought the scheme would improve water quality/quantity	44 (62.9)	11 (15.7)	14 (20.0)	19 (27.5)
D	... I was already concerned with conservation before this scheme	26 (37.1)	8 (11.8)	7 (10.0)	11 (15.9)
E	... I like the forest and I wanted to have a bit in my farm	20 (28.6)	4 (5.7)	9 (12.9)	7 (10.1)
F	... With more trees my cattle would have more shadow	14 (20.0)	2 (2.9)	6 (8.6)	6 (8.7)
G	... I believed the farm would appear more organized/beautiful with the interventions proposed	11 (15.7)	4 (5.7)	4 (5.7)	3 (4.3)
H	... I like that others are concerned with our community	13 (18.6)	1 (1.4)	7 (10.0)	5 (7.2)
I	... In our community we all are interested in participating in environmental projects	3 (4.3)	1 (1.4)	0 (0)	2 (2.9)
J	... My neighbors were already in the scheme	4 (5.7)	0 (0)	4 (5.7)	0 (0)
K	... The economic incentives caught my attention	6 (8,6)	0 (0)	1 (1.4)	5 (7.2)
L	... Of other non-mentioned motivations	3 (4,3)	0 (0)	1 (1.4)	2 (2.9)

5.3.2 Importance of evidence of PES impacts

Intermediaries: Intermediaries were asked whether they feel it is important to report/communicate PES impacts on water-related ES (e.g. water turbidity reduction, river discharge increment, etc.) to payers (Table 5-6). 96% of respondents (n=24) totally agreed that it is important, while 4% (n=1) mostly agreed. Following, they were asked whether they feel that payers expect them to demonstrate PES impacts on water-related ES. The question did not include the expectation over indicators of activities performed (e.g. number of planted trees), but only indicators regarding water-related ES. 68% of respondents (n=17) totally agreed about the payers expectation, while 24% (n=6) mostly agreed, 4% (n=1) neither agreed nor disagreed, and 4% (n=1) mostly disagreed.

Following, intermediaries were asked whether they agree that demonstrating PES impacts on the target water-related ES was important for the reputation of their organizations (Table 5-6). 68% of respondents (n=17) totally agreed, 20% (n=5) mostly agreed, while 8% (n=2) neither agreed nor disagreed, and 4% (n=1) mostly disagreed. Interviews further confirmed the intermediaries' concerns on proving the effectiveness of their schemes in terms of water-related ES indicators for the sake of their reputation. However, this was not the only reason pointed. Interviewees expressed that they are concerned about demonstrating PES impacts on ES also because: (1) they want to keep payers on board, (2) they want to attract more potential payers by demonstrating the effectiveness of their schemes, (3) they want to keep good relations with the providers who entered the scheme motivated by environmental awareness, (4) they feel personally engaged with the cause and want the schemes to be successful. It was also observed in the field that NGOs and civil associations employ several technicians and managers to work in the PES scheme and lack of funding would mean unemployment for many of them. Therefore, evidence of an effective conservation scheme also supports more stable working conditions.

Table 5-6: Summary of intermediaries' respondents answers to agreement questions.

id	Agreement Statement	# Answers	Totally Disagree	Partially Disagree	Neither Agree nor Disagree	Partially Agree	Totally Agree
			abs (%)				
A	It is important to communicate PES impacts/outcomes to those who are supporting and paying this scheme	25	0	0	0	1 (4.0)	24 (96.0)
B	Those who are supporting and paying this scheme expect us to demonstrate PES impacts	25	0	1 (4.0)	1 (4.0)	6 (24.0)	17 (68.0)
C	Those who are supporting and paying this scheme only pay under the condition of PES impacts being demonstrated	25	6 (24.0)	2 (8.0)	9 (36.0)	4 (16.0)	4 (16.0)
D	I think that demonstrating PES impacts is important for the reputation of those in charge of the schemes	25	0	1 (4.0)	2 (8.0)	5 (20.0)	17 (68.0)
E	PES schemes are too new to be able to generate impacts that could be detected on water-related ES	25	1 (4.0)	1 (4.0)	7 (28.0)	1 (4.0)	15 (60.0)

Payers: payers' respondents were asked how much they agree that their organizations required regular reports of environmental indicators monitoring from PES intermediaries (Table 5-7, item E). 9 respondents totally agreed (60%), 3 mostly agreed (20%), 1 neither agreed nor disagreed, 1 mostly disagreed and 1 totally disagreed. In the same line, respondents were asked how much they agree that they only require reports about the activities performed by the PES intermediaries but not about the impacts of these activities on the environmental services of interest (item F). Most of the respondents disagreed (66.7%), while 26,6% agreed and 6.7% (1 respondent) neither agreed nor disagreed.

Table 5-7: Summary of payers' answers to agreement questions.

id	Agreement Statement	# Answers	Totally Disagree	Partially Disagree	Neither Agree nor Disagree	Partially Agree	Totally Agree
			n (%)				
A	We believe that ES will improve with the PES scheme	15	0	0	1 (6.7)	5 (33.3)	9 (60)
B	The most important motivation for engaging was the improvement of environmental service	15	0	0	2 (13.3)	2 (13.3)	11 (73.3)
C	We only pay under the condition of PES impacts being demonstrated	15	6 (40)	2 (13.3)	1 (6.7)	5 (33.3)	1 (6.7)
D	If PES impacts on environmental services are not proven with the time, we would stop paying for the scheme	15	4 (26.7)	2 (13.3)	2 (13.3)	4 (26.7)	3 (20)
E	We require reports with monitoring results of PES impacts on environmental services regularly	15	1 (6.7)	1 (6.7)	1 (6.7)	3 (20)	9 (60)
F	We only require reports of activities performed, not of PES impacts on environmental services	15	7 (46.7)	3 (20)	1 (6.7)	2 (13.3)	2 (13.3)

5.3.3 Payment upon evidence of PES impacts

Intermediaries: intermediaries were asked whether they agree that payers pay (or will keep paying) under the condition that PES managers provide proofs of PES impacts on ES (Table 5-7). This question raised no clear consensus: 36% of respondents (n=9) neither agreed nor disagreed, while those who mostly or totally disagreed summed 32% (n=8), and the same was obtained for those who mostly or totally agreed (32%, n=8). During the interviews, questions regarding to this point also raised uncertainty among intermediaries. However, most of them expressed that although reporting progress in terms of PES impacts on water-related ES was important and required by payers, payers do not appear to be willing to leave the scheme in case no proof was delivered. When questioned about potential reasons, several interviewees pointed that although payers were interested in the ES, they also engaged in the scheme because of other motivations. Table 5-8 presents their opinion about potential motivations from payers (separated in two categories only, private and public companies).

Table 5-8: Perception of intermediaries about the payers' motivations (restricted here to private and public companies) to engage in the water-related PES schemes under study (non-exclusive motivations).

Id	Intermediaries' Perceptions of Payers' Motivations	Count (out of total = 25)	Frequency [%]
	Private Companies		
A	ES improvement	19	76
B	Corporate socio-environmental policy	19	76
C	Corporate image. Green marketing	22	88
D	Improvement of private-public relations	12	48
K	Environmental compensation required by law	14	56
L	Other	1	4
	Public Companies		
A	ES improvement	18	72
B	Corporate socio-environmental policy	9	36
C	Corporate image. Green marketing	13	52
D	Improvement of private-public relations	13	52
K	Environmental compensation required by law	10	40
L	Other	6	24

Payers: Payer's representatives were then asked how much they agree that their payments were conditional on evidence of ES improvement to be provided by intermediaries (Table 5-7, item C). The question divided respondents; 8 out of 15 respondents disagreed (53.3%) and 6 of them agreed (40%), while 1 neither agreed nor disagreed. Average value for this question was 2.53, indicating a trend towards disagreeing. Following, payers were asked how much they agree that their organizations would leave the scheme in case no ES improvement is proven over time (item D). 4 respondents totally disagreed, 2 mostly disagreed, 1 neither agreed nor disagreed, 4 mostly agreed, and 3 totally agreed. Average value reached for this answer was 3.0, indicating that respondents answers balanced towards the agreement value.

During interviews, payers indicated in their answers that ES improvement is important and is the main driver for their engagement. However, most of them have entered the scheme for additional reasons, confirming the results obtained with intermediaries. Additional reasons reported included better relations with local communities, green marketing, etc. Payers expressed that most of them would not stop paying in case ES improvement is not proven. Reasons for that included: (a) most of the payers understand that water flows in a watershed is a result of complex processes and monitoring is costly; (b) payers invest part of their money for environmental compensation and other legal requirements and, therefore, engaging in a PES scheme fits those requirements; (c) additional motivations pay-off; (d) big companies are somehow used to fund risky investments and PES costs are not large enough to compromise their budget.

For some of the payers' respondents, not achieving the ES goals was not a major concern: one beverage company interviewee expressed that they would keep paying because even without getting better water quality, that would not be a big issue for the company because any additional cost on water treatment for beverage would be passed to consumers through an increase in price. For one water supply company, the PES scheme was part of a whole strategy on conservation that was already established in the company's core functioning. Therefore, even if the PES scheme does not achieve the expected outcomes, other internal conservation projects would play a role on satisfying environmental concerns. Another respondent from a beverage company expressed that although the outcomes of such schemes were highly uncertain their company already had environmental concerns as part of their core values. Moreover, as in any other investment, companies are used to take risks and deal with uncertain situations.

5.3.4 Environmental indicators of interest

Payers: payers representatives received a list of potential environmental and social indicators and were asked to choose the ones that their organization had required reports from intermediaries. In addition, they had the option of adding new ones to the list. In sequence, they were asked to choose the first, second and third most important indicators (Table 5-9). All 15 respondents selected the indicators, however just 12 indicated their first, and 9 chose their second and third most important ones. The most selected indicators were A to F. While indicators A to E refer to the conservation practices performed in the field, F refers to a social indicator. None of these five indicators is related to the ES outcomes, i.e. the ES maintenance or improvement obtained from the conservation practices. However, when asked about their first most important indicator, 33.3% of respondents (n=4) said river discharge increment (item H), would be their choice. Area under vegetation protection (item A) follows as first choice for 25% of respondents (n=3). Area under vegetation protection and sediment load reduction (item J) were chosen as second most important motivation by 2 respondents each. Number of planted trees (item B) was chosen by 4 respondents (44.4%) as the third most important motivation.

The fact that the most important indicators selected by payers are not related to ES outcomes but rather to proxies could be due to three potential explanations drawn from interviews: (i) Payers strongly believe in a positive interaction between vegetation protection and water-related ES maintenance; (ii) payers are more inclined to use those indicators as numbers to their annual sustainability reports for their clients, government, shareholders or local community; for that matter indirect indicators of conservation, i.e. proxies, would be sufficient; (iii) at least part of the payers are aware that ES monitoring is not easy to perform and is expensive, therefore, they would rely on proxy indicators as metrics for PES effectiveness.

As one of the payers from a water supply company reported on an interview: "Impact indicators are more important, i.e. those who reflect the benefit of the activities performed, however it is not always possible to get them due to information availability issues or the cost of getting information. Therefore, we should seek a balance in those terms (Bogotá, June 2016). " These results apparently contradict a comment made by one PES manager that said, "business men who are investing in those payments schemes expect that scientists could come with an equation that would tell them for every dollar spent how much water quality improvement they will gain in return (Medellín, February 2015)."

Table 5-9: Payers' selection and ranking of social/environmental indicator of interest.

id	Social / Environmental Indicator	# selections total=15 n (%)	# selected 1st total=12 n (%)	# selected 2nd total=9 n (%)	# selected 3rd total=9 n (%)
A	Area under vegetation protection	12 (80)	3 (25)	2 (22.2)	1 (11.1)
B	Number of planted trees	12 (80)	1 (8.3)	1 (11.1)	4 (44.4)
C	Area under vegetation recovery	9 (60)	1 (8.3)	1 (11.1)	0
D	Number of water springs protected	8 (53.3)	0	1 (11.1)	1 (11.1)
F	Number of families receiving payments	8 (53.3)	1 (8.3)	1 (11.1)	1 (11.1)
G	Length of protected river margins by fencing	7 (46.7)	0	0	0
H	River discharge increment	7 (46.7)	4 (33.3)	1 (11.1)	0
I	Number of individuals trained	6 (40)	0	0	0
J	Sediment load reduction	5 (33.3)	0	2 (22.2)	0
K	Water turbidity reduction	5 (33.3)	0	0	0
L	Regulated river discharge during dry seasons	5 (33.3)	0	0	1 (11.1)
M	Regulated river discharge during wet seasons	3 (20)	0	0	0
N	Families income increment	3 (20)	0	0	0
O	Nitrogen/Phosphorus concentration reduction	2 (13.3)	1 (8.3)	0	1 (11.1)
P	Fertilizer use reduction	1 (6.7)	0	0	0
Q	Pesticides use reduction	1 (6.7)	0	0	0
R	Physical-chemical parameters of water quality	1 (6.7)	1 (8.3)	0	0
S	Other non-mentioned indicator	1 (6.7)	0	0	0

5.4 Discussion

5.4.1 Who is interested in evidence of PES environmental impacts?

Intermediaries are concerned about getting impact evidence of their schemes on ES for several reasons, most of them linked to their wish to keep their *modus operandi*. Evidence of ES improvement or maintenance would support keeping payers on board, attract more payers in the long term, sustain conservation jobs, and maintain trust relationships with both payers and providers. These concerns are seen on interviews, questionnaires and are similar to those found in the practitioners literature (e.g. Bremer et al., 2016; Higgins and Zimmerling, 2013). Intermediaries are also clearly concerned about their reputation as PES managers and are aware that providing evidence of PES impacts on ES is a central issue on this matter. This result is consistent with the one obtained by Fisher and Brown (2014) regarding the use of the ES concept and its derived tools by conservation practitioners. The cases analyzed provide some evidence that personal values also play a role on the intermediaries' concerns with the evidence of PES impacts. Most of the interviewed representatives feel personally engaged with the local communities in which they work and with the environmental issues, and want the schemes to be effective.

Payers do expect evidence of environmental benefits achieved by the scheme in terms of ES and expect intermediaries to perform monitoring and report its results. Answers from both payers and intermediaries' perceptions about payers' demands pointed to this direction. However, when it comes to express the most important indicators for them, payers would mostly point to proxy indicators, e.g. total area protected or number of planted trees, instead of selecting more indicators linked to the target ES, e.g. decrease of nitrogen and phosphorus concentration on water. Potential reasons may include the importance of indicators mostly for the sake of corporate sustainability reports in which specific indicators are not needed, or due to an assumption that proxy indicators are directly related to the desired ES.

Providers are also interested in the PES impacts. Questions regarding motivation to engage in the scheme were able to capture their interest in the ES itself, instead of solely the payment, either in cash or in kind, for performing conservation practices in their properties. Most of them pointed water resources conservation as one of the most important motivations and declared that they would engage in the scheme even without economic incentives. These results contradict the simplistic idea of a "service provider" as proposed in the literature (Wunder, 2005) and give clear indication that the so-called providers understand themselves as ES beneficiaries too and are willing to cooperate for conservation in case they receive technical and material support for that. Other recent studies in Latin-American cases have pointed to similar results. Bremer et al. (2014) showed that in Ecuador, landowners were motivated to participate in the program for a variety of reasons, including a "high value placed on the water provisioning services of the páramo [ecosystem] (Bremer et al. 2014, p. 122)." Intrinsic motivations have been also found in parallel with utilitarian arguments among landowners in other Latin-American cases. For instance, (Kosoy et al., 2008) found that indigenous groups participating in conservation schemes in Mexico had religious reasons in addition to the concerns with the forest provision of benefits. They considered forests as "sacred" places, with caves and other sites being used as temples (Kosoy et al., 2008, p. 2080). In another study, a desire to "care for the land" was found as one of the main motives for participation in PES schemes in Mexico (Méndez-López et al., 2015, p. 695).

In part, the results found in this study could be a consequence of the discourses held in the field by intermediaries while negotiating with landowners. Most of the intermediaries in the studied cases do not frame the proposed conservation practices as something that would only benefit downstream users but most of them emphasize the benefits that conservation will also have for those who live upstream. They argue that protecting water bodies, like springs and creeks, is fundamentally important for the providers themselves. During interviews, it became clear that providers tend to assume that the conservation practices are good for their own sake. Interviewed landowners often argued that "a farm without water has no value". In fact, the same water resources are shared and used by all, although distributed unevenly throughout the watershed.

5.4.2 Why those schemes keep working if there is no evidence of improvement of the target ES yet?

Most of respondents from the three groups in all four schemes perceive the lack of evidence as a matter of time, because the schemes under study are relatively new and that the monitoring process is still incipient, as registered in interviews and questionnaires. They understand that the watershed would require more time to respond to the conservation practices undertaken. Still, most of the respondents from both providers and payers groups showed that they believe the scheme will produce beneficial ES outcomes. This may be explained by the presence of the common belief that "more forest leads to more water quantity" and better water quality (Kosoy et al. 2007, p. 451) in the discourses from both providers and payers, according to the interviews.

An additional explanation for the perseverance of such schemes relies on the extra benefits it brings to actors. It appears that PES fit well into the agenda of several of them, mainly of the intermediaries and payers. Intermediaries benefit from this approach due to the central role they must play to sustain such a scheme as several tasks involved in the PES design and implementation are required, such as property rights verification, constant visits to the field, and one-by-one negotiation with local farmers (Vatn 2010). As noted by Pham et al. 2010, intermediaries also act as information providers, mediators, watchdogs, arbitrators and bridge builders, among a series of other functions. Vatn (2010, p. 1247) concludes that "this explains why in PES schemes the intermediary is the dominant agent — whether the state, firms or NGOs of various kinds. The intermediary defines the good, establishes the group of 'sellers' and 'buyers' and even often set a predefined price."

At the same time, the strong presence of the ES approach in the global conservation agenda since the Millenium Ecosystem Assessment (MA, 2003) means that more funding through international cooperation is available for this type of approach (Fisher and Brown, 2014). In the studied cases, CSAH Cali received funds from the government of Netherlands, and the Latin American Water Funds Partnership received funds from United States Agency for International Development (USAID) and from the Inter-American Development Bank (IADB). In particular, PES have been recently assuming an important position in the environmental institutional configuration in Colombia through several laws and decrees (Rojas-Sanchez, 2014). It has been promoted as a national conservation strategy that culminated with the announcement (7th July 2017) of the new "Payment for Environmental Services Policy" by the Colombian Ministry of Environment and the National Department of Planning PES schemes are expected to escalate (MINAMBIENTE, 2017). Thus, working with the ES approach could mean more funding available for the conservation business and, therefore, more jobs.

From the payers' side, although ES improvement was the first motivation to enter the scheme for more than half of respondents, additional ones play a strong role. Their participation fulfills other demands, e.g. corporate socio-environmental policy, improvement of corporate image, better local relations, and legal environmental requirements. These additional payers' motivations were clearly identified by both interviewed intermediaries and payers and could explain a potential permanence of payers in the schemes even without evidence of PES impacts on the target ES.

Although the literature on why firms engage in PES schemes as payers is almost non-existent, there are several papers discussing the reasons behind the adoption of corporate socio-environmental policy (CSR), which respondents pointed as one of the main reasons for the adoption of PES. CSR can be understood as "context-specific organizational actions and policies that take into account stakeholders' expectations and the triple bottom line of economic, social, and environmental performance (Aguinis 2011, p. 855)."

Hemingway and Maclagan (2004) discussed the hypothesis of managers' personal values influencing the adoption of CSR practices by their companies. They proposed that cultural factors, such as religious beliefs and moral values of managers, could play an important role. Vives (2006) presented a survey covering more than a thousand small and medium firms in Latin America that had implemented responsible practices of a variety of types. The major motivations found by Vives were increment profits, but also religion/ethics, motivating workforce, and building relationships. In a survey with corporate leaders, Ditlev-Simonsen & Midttun (2011) found that branding and reputation were the primary CSR drivers among Norway companies. Babiak & Trendafilova (2011) studied the motives behind the adoption of environmental management practices as part of CSR among U.S. sports leagues. They found that strategic and legitimacy motives, connected to the need to address institutional pressures and social expectations, were among the main drivers of the CSR adoption. Executives also associated these choices with increasing chances for financial collaborations with sponsors that were interested in environmental issues. Thus, although economic motives exist, social norms are also important. Indeed, as pointed by organizational sociology scholars, organizations are particularly attentive to what other organizations do when adopting certain practices (Aldrich, 2007). Firms may experience pressure from organizations upon which they depend, emulate other organizations because of their success, or just follow the advice of professional associations from their sector (DiMaggio and Powell, 1983). Exploring the extent to which such "institutional isomorphism" applies to PES programs may have implications also for our understanding of their endurance.

5.4.3 Will PES schemes survive in the long-term if there is no evidence of the expected environmental outcomes?

The results indicate that providers from the studied cases are willing to take part on some costs to adopt conservation practices, e.g. by setting aside part of their arable land for vegetation protection, if there is an incentive for that, i.e. if they are not the only ones to bear the costs.

As one interviewee expressed, “I have always been concerned with conservation and I expect that with the economic incentives I can dedicate my land to protect water springs without affecting my income for that”. As most providers are engaging motivated mainly by water resources conservation, if the desired environmental impact is not met in the long term, there is a chance that they would drop out from the scheme not because of lack of economic incentives, but mostly because their expected benefits in terms of ES were not achieved. Under this assumption, evidence of PES environmental outcomes is therefore important not only to keep payers on board, but also providers.

When intermediaries were asked if payers would only pay under the condition of PES impacts being demonstrated they showed considerable disagreement with a balanced answer rate along the Likert scale. This result is consistent with the one obtained from the payers when asked if they would only pay under the condition of PES impacts being demonstrated. When asked if they would stop paying in case the ES improvement is not achieved with the time, payers again showed disagreement, with answers relatively balanced along the scale. Potential reasons for the disagreement can be that while improvement of ES remains the most important motivation for them to engage in this type of scheme, still the additional motivations they have play an important role in their decisions as previously discussed.

Although the answer for the proposed question remains dependent on additional empirical research, the present study demonstrates that several motivations are behind the engagement of providers, intermediaries and payers in PES schemes. The perceived additional benefits the actors have while participating in such schemes may partly explain the future long-term maintenance of this conservation approach even under lack of evidence of their impacts.

5.4.4 Limitations of this study

We believe the results presented here can shed some light into the issue of the long-term durability of PES schemes; however, it is worth mentioning that the scope of this study is limited to the four cases presented and, therefore, more research would be needed to test similar hypotheses in the field. In addition, the low response rate obtained among payers is of some concern, as in the studied cases they are usually managers of large organizations and have a limited time for interviews or questionnaires. However, several firms that responded the questionnaire are among the largest ones in Colombia and their funding for conservation is expressive. A second concern refers to the accessibility to the field in this type of scheme. As intermediaries are the ones who know exactly who the schemes' providers are and where they live, it is very hard to perform interviews and questionnaires without the presence of at least one manager or technician belonging to the intermediaries group. We believe that in occasions in which is not possible to avoid their presence while interviewing, answers from providers may be partially biased as some of them would be concerned with not threatening the trust relationship developed with the intermediaries. Whenever it was possible, questionnaires were conducted without the practitioners presence, and double-check of answers was performed through interviews. Finally, we are aware that the use of Likert Scale can introduce biases to the answers; in order to address this, we built questionnaires based on preliminary interviews and additional interviews were undertaken in order to confirm first answers or to receive explanations on the choices made.

5.5 Conclusion

There is not a straightforward answer for whether PES schemes will survive in the long term in the absence of evidence of their environmental benefits. What it is clear is that the lack of evidence has been already a matter of criticism from the scientific community and a matter of concern among PES intermediaries. In this paper we explored four water-related PES schemes in which became clear that the evidence of environmental outcomes is important not only for those who pay for the schemes but also for intermediaries and the so-called providers. However, as PES schemes have important indirect benefits, mainly for the intermediaries and payers, there is a chance that those schemes will survive the lack of effectiveness evidence in the long-term if that depends solely on these groups' wishes. However, as providers understand themselves also as ES beneficiaries, the lack of evidence of expected PES environmental outcomes could discourage their permanence in the schemes

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6 Synthesis and Conclusion

6.1 Overview

After two decades of PES implementation worldwide, doubts have been raised about their effectiveness, particularly in the case of payments for watershed services (PWS). The assessment of effectiveness is justified given the large amounts of money that governments, particularly those from developing countries, have invested in the schemes.. Such assessment, however, faces substantive barriers.

In this dissertation, I have explored the role of uncertainty in the assessment of the effectiveness of PWS. Specifically, I have focused on three aspects: (a) the sources and types of uncertainties in these schemes that may hinder the feasibility of demonstrating effectiveness; (b) the current efforts and practical constraints to produce the evidence of PWS impact on target ES; and (c) the role of impact evidence on the enduring participation of providers and payers in the schemes and the long term durability of the schemes. To address these points, I have applied an interdisciplinary approach focusing on the science-policy interface of PWS schemes, and combining disciplinary elements from Ignorance studies, Hydrology, Institutional and Ecological Economics, and Public Policy.

From Ignorance Studies, I have reviewed the literature on uncertainty and knowledge gaps in the conservation policy decision-making process. From Hydrology, I have reviewed the core literature on land and water interactions, with a focus on the impact of land use/cover on key hydrological processes such as runoff, infiltration, erosion, sedimentation and those related to water quality. The expertise gained though the revision of ignorance and hydrology scholarship allowed me to carry a critical assessment of the uncertainty behind a number of hydrological processes that are frequently taken for granted in PWS schemes (Chapter 3).

From Public Policy scholarship, I used the literature on policy evaluation, which has a relatively long tradition in the study of impact evaluation, and evidence-based decision making. Specifically, I explored the concepts of additionality, counterfactual evidence, monitoring, case-control and baseline, and applied them to analyze the current status of seven PWS schemes in Colombia and Brazil regarding the efforts to produce evidence of additionality. Also building on the knowledge gained from hydrology scholarship, I described the characteristics of the land use, contract compliance, and hydro-climatological monitoring practices currently undertaken by intermediaries in the seven cases and the efforts made and challenges faced to obtain baseline data and to set up control catchments (Chapter 4).

From Institutional and Ecological Economics, I explored key concepts from the literature on environmental governance, incentive-based policy tools, transaction costs, intrinsic versus extrinsic motivation for conservation, and corporate social responsibility. The knowledge gained through those two disciplines constituted the basis to carry a comparative case study of four PWS in Colombia with a focus on the expectations of three groups of stakeholders (payers, intermediaries, and providers) on the outcomes of the schemes in which they are engaged, and their perception about the role of evidence of effectiveness on the long-term durability of the schemes. Using literature from corporate social responsibility and from motivations for conservation, I explored the motivations to engage from both providers and payers, demands from both groups towards intermediaries, and the institutional reasons that explain why intermediaries are seeking to demonstrate additionality. I also explored the role of external motivations for payers to engage in PWS and the relative importance of evidence of effectiveness in their permanence on the scheme (Chapter 5).

To carry the above-mentioned studies, I combined empirical methods for quantitative and qualitative research, such as informal interviews, semi-structured interviews, survey-type questionnaires. Participant observation was also key for data collection as it allowed me to follow intermediaries in the field, observing their daily activities, their dialogues with both providers and payers, and taking notes in the field while observing hydrologic monitoring routines. In order to complement the information obtained directly through contact with stakeholders, I thoroughly reviewed official documents and reports from the intermediaries, such as contracts, regulations, organigrams, technical studies, scenario analyses, project proposals, and field visit and monitoring reports.

6.2 Main insights

PWS schemes have a long road towards additionality evidence, if they ever get there. Assessing additionality as promoted in the literature, i.e. clearly defining unequivocal effects of interventions has been arguably infeasible in most cases so far. In the presented studies, I built on previous literature to demonstrate that three major factors interact to produce high uncertainty on PES environmental outcomes, particularly on PWS cases: (1) complexity of Human-Environmental Systems; (2) lack of knowledge about these systems associated; and (3) practical constraints. Eventually, these factors may prevent the demonstration of additionality in PWS.

The schemes studied are responding to an increasing international demand for impact evaluation. Almost all schemes are gradually enjoying the implementation of monitoring systems as a result of the collaboration between intermediaries and local research centres. However, in the majority of the schemes studied, no baselines of important environmental variables and no monitoring protocols were established from the start, and this is severely compromises evidence of additionality. Additionally, there are a series of practical constraints, including most notably the lack of continuous funding due to the voluntary character of such schemes and data sharing issues.

In the context of such efforts to demonstrate effectiveness, it is worth asking to whom impact evidence is important and why. Through the four studied cases in Colombia, I showed that intermediaries are concerned about getting impact evidence of their schemes for several reasons, most of them linked to their wish to keep the business running. Evidence of ES improvement or maintenance would contribute to keeping payers on board, attracting more payers in the long term, sustaining conservation jobs, and maintaining trust relationships with both payers and providers. Intermediaries are also clearly concerned about their reputation as PES managers are aware that providing evidence of PES impacts on ES is a central issue on this matter. Personal values also appear to play a role on the intermediaries' concerns with the evidence of PES impacts. Most of them feel personally engaged with the local communities with which they work and with the environmental issues, and want the schemes to be effective.

Payers expect evidence of environmental benefits achieved by the scheme in terms of ES and expect intermediaries to perform monitoring and report its results. However, when it comes to express the most important indicators for them, payers are interested in more proxy indicators, e.g. total area protected or number of planted trees, than in a larger number of indicators linked to the target ES, e.g. decrease of nitrogen and phosphorus concentration on water. Potential reasons may include the importance of indicators mostly for the sake of corporate sustainability reports or due to an assumption that proxy indicators are directly related to the desired ES.

Providers are also interested in the PES impacts. Most of them pointed water resources conservation as one of the most important motivations and declared that they would engage in the scheme even without economic incentives. These results contradict the simplistic idea of a service 'provider' or 'seller' as proposed in the literature (Wunder, 2005) and give clear indication that the so-called providers understand themselves as ES beneficiaries too and are willing to cooperate for conservation in case they receive technical and material support for that. Providers tend to assume that the conservation practices are good for their own sake. Interviewed landowners often argued that "a farm without water has no value". In fact, the same water resources are shared and used by all, although distributed unevenly throughout the watershed.

It is not known if the lack of demonstrable effectiveness of PES schemes due to high uncertainty will threaten the long term durability of these schemes. I argue that, although producing evidence of additionality in terms of ES as preconized in the literature is infeasible in most cases, there is chance that PES schemes will endure in the long term due to the extra benefits they bring to certain actors. Because of indirect benefits (see Chapter 5), mainly for the intermediaries and payers, there is a chance that those schemes will survive the lack of effectiveness evidence in the long-term if that depends solely on these groups' wishes. However, as providers understand themselves also as ES beneficiaries, the lack of evidence of expected PES environmental outcomes could discourage their permanence in the schemes.

6.3 Policy Recommendations

By assuming that the most used definition of PES, together with the increasing calls for evidence of additionality, are in conflict with the reality of our complex human-environmental systems, I have proposed a model for adaptive PES management (Chapter 3). In this adaptive model, PES design is embedded in a loop that is continuously permeable to new information and surprises shared among the stakeholders. Whenever possible, there is an explicit assessment of uncertainty sources and an emphasis on a collective project evaluation, including the participation of intermediaries, payers, and also providers. By these means, I emphasize that relevant knowledge about HES is produced not only by scientific methods, but also by non-scientific knowledge through participation of those who actually live in the area under management. I argue that an adaptive approach to PES that accounts for uncertainty through an open dialogue with stakeholders and integrates providers' standpoints, instead of a top-down measure set up among only intermediaries and payers, may produce a more legitimate process.

Finally, I propose that in designing PES schemes, stakeholders should explicitly address and communicate with each other about uncertainty in order to have a clearer picture of potential ways to progress, cope with and adapt to unforeseen circumstances, and eventually ensure the long term viability of the conservation projects. However, it is important to keep in mind that uncertainty may be used selectively, downplayed or amplified in politics to suit vested interests or keep unequal power relations. Transparent treatment of uncertainty is fundamental to managing expectations, build trust among actors and maintain credibility of PES practitioners. If recognizing and accounting for uncertainty is to threaten the success of PES schemes, then uncertainty can be seen as an opportunity to open up dialogue about alternative ways of achieving the conservation goals.

6.4 Opportunities for future research

The study of uncertainty in PWS schemes has many venues for future research. In particular, the following topics are still under-researched and further developments on them could support more in-depth discussion about the implications of PWS use to fulfill conservation goals. Here I present some of them.

Magnitude of quantifiable uncertainties in PWS mechanisms: There are several types of uncertainty that cannot be quantified and any attempt to do so could induce a wrong assumption of control and predictability that may be incorrect (Wynne, 1992). However, there are some types that can be quantified (e.g. McMillan et al. 2012) However, there are other uncertainties that are amenable for quantification, the outcomes of which could work as illustrative examples that would help policy makers, conservation investors, and other stakeholders understand the reliability of the evidence they use to make decisions. Some researchers have already started exploring the challenges and opportunities represented by the quantification of uncertainties on ES (e.g. Hamel & Bryant 2017); however there are only few studies dedicated to accounting for uncertainty on PES mechanisms.

Reactions to scientific uncertainty: Another interesting strand of research refers to how stakeholders perceive and react to communicated uncertainty in PES schemes. There are several debates in the science-policy interface literature concerning the potential reactions of decision-makers and the public towards scientific uncertainty and how to cope with uncertainty and risk in a variety of environmental problems (e.g. Todini & Mantovan 2007; Hall et al. 2007; Beven 2006; Stirling 2008; Stirling 2010; Funtowicz & Ravetz 1990). However, there is still a lack of empirical behavioral studies contemplating the reactions and potential changes on the decision-making process caused by a transparent treatment of uncertainty among stakeholders involved in PES schemes.

Ambiguity and lack of clarity as sources of uncertainty in the PES literature: one of the challenges imposed by the avalanche of PES articles, cases, and reports worldwide is the fragile conceptual basis, the ambiguity, and the lack of clarity (Carey and Burgman, 2008) regarding concepts and processes. The distance between claims in the literature and the reality of processes in human-environmental systems is not the only concerning point. The literature is also permeated with misconceptions and ambiguity regarding basic terms such as 'service', 'service provider', 'ecosystem', 'area of influence', etc. (Barnaud and Antona, 2014; Boyd and Banzhaf, 2007; Hill, 1977; Kull et al., 2015; O'Neill, 2001; Robertson, 2012).

Participatory approaches to cope with uncertainty: the understanding and learning processes about human-environmental systems may be greatly improved through transdisciplinary approaches that take in to account not only scientific methods, but also non-scientific knowledge from local experts (Krueger et al., 2012; T. Krueger et al., 2016). There is considerable room for empirical studies on the effects of such approaches on the quality and legitimacy of environmental studies that are used to support conservation policy and management.

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Appendix I

Conservation Projects: monitoring and evaluation practices

Dear Sir./Madam, thank you for your time and dedication to this survey. This questionnaire is part of a scientific research project that has the goal of evaluating the conservation projects that have been implemented in Colombia. This is part of a project supported by Humboldt-Universität zu Berlin, Germany, and Pontificia Universidad Javeriana, Bogota, Colombia.

It is important to note that some questions are made using a scale of agreement from 1 (totally disagree) up to 5 (totally agree). Please select 3 in case you are not in agreement or disagreement. If the question does not apply to you or you do not know the answer, please leave the question without an answer.

1. Please, mention the country in which the project you are working with is located. In case there are more than one, mention all of them.

2. In which professional position related to a PWS project are you currently involved?
[ ] project manager
[ ] technician (example: monitoring, mapping/GIS, modelling, management, project implementation, auditing, others)
[ ] scientist (example: in charge of primary research for the PWS project)
[ ] other. Specify in the last part of this survey dedicated to comments.

3. What is your highest academic degree?
[ ] bachelors
[ ] specialization
[ ] masters
[ ] PhD
[ ] does not apply

4. What is your academic background? Example: economist, manager, biologist, geographer. Please, include your specialization/masters/PhD degree description.
____
____

5. What is the role your organization has in a PWS project?
[ ] civil entity created specifically to manage a PWS
[ ] regional autonomous corporation in charge of managing a PWS
[ ] non-governmental organization in charge of the design of a PWS
[ ] non-governmental organization in charge of implementing a PWS
[ ] non-governmental organization directly in charge of the management of a PWS
[ ] non-governmental organization in charge of providing support for a PWS
[ ] private environmental consulting in charge of evaluating a PWS

6. What is the degree of responsibility on monitoring of environmental variables in PWS projects that your organization has?

[ ] the organization is directly in charge of performing monitoring
[ ] the organization is in charge of funding/paying for the monitoring
[ ] the organization is in charge of the logistics for the monitoring
[ ] the organization is in charge of getting monitoring data from third parties
[ ] the organization is in charge of processing and communicating results from monitoring
[ ] the organization does not have any type of responsibility over the monitoring processes or their results

<u>Monitoring system and baseline of environmental variables in the context of the PWS projects</u>

The following questions refer to the process of monitoring and constructing baselines of environmental variables (example: nitrogen concentration on water) that allow for the detection of expected environmental results (example: reduced contamination of nitrogen) on activities developed in the context of the PWS projects.

In the following statements, please select the option that matches most closely your degree of agreement with these statements. The options range from 1 (totally disagree) up to 5 (totally agree). Please select 3 in case you are not in agreement or disagreement. If the question does not apply to you or you do not know the answer, please leave the question without an answer.

7. The PWS projects have a good baseline regarding the environmental variables directly linked to the watershed service (example: discharge, turbidity, etc.), in a way that allows for the comparison of the previous state (before beginning conservation activities) and a posterior state (after the beginning of the activities, which is, the impacts of PWS schemes).

Explanation: baselines refer to historic series of data about the variables that allow for a characterization of the watershed dynamics where the PWS project has been implemented. Example: discharge baseline refers to a series of many years of observational data that allows for the characterization of the river flow and typical seasonal behavior.

[1] [2] [3] [4] [5]

8. The PWS project has good monitoring systems of environmental variables related to the conservation activities implemented by the project.
Explanation: environmental variables of importance can include, for example, water level, nutrient concentration on water, turbidity, sediment concentration, etc.

[1] [2] [3] [4] [5]

9. The PWS project are too new to produce results/impacts that can be detected on the watershed services.
Explanation: the water quality data do not show any change that can be attributed to the implemented activities yet.

[1] [2] [3] [4] [5]

10. The PWS project has monitoring data, but the TEMPORAL frequency of the sampling is not enough to detect the result/impact of the activities implemented that are related to the watershed services.
Explanation: when the temporal frequency is not enough it means that it happens rather unfrequently (example: only once per year) and that makes it harder to detect the impacts on water quantity/quality/regulation).

[1] [2] [3] [4] [5]

11. The PWS project has monitoring data, but the SPATIAL distribution of the sampling is not enough to detect the result/impact of the activities implemented that are related to the watershed services.
Example: when the water sampling does not happens close to the stream under influence of the conservation activities but far from it, where the influence of other land uses cannot be separated.

[1] [2] [3] [4] [5]

12. The PWS projects have monitoring data, but the data does not cover the important variables for the detection of results/impacts of conservation activities developed on the watershed service.
Example: when there is a need to monitor sediments, but there is only measurement of suspended solids and not of riverbed sediments.

[1] [2] [3] [4] [5]

13. The PWS projects have monitoring data, but the data have inconsistencies or errors that make it hard to detect the results/impacts of the conservation activities on the watershed services.
[1] [2] [3] [4] [5]

14. I believe that the problems and difficulties with PWS environmental monitoring make hard the detection of results/impacts of the conservation activities implemented on the environmental service.
Important: in case there are no problems leave it blank.

[1] [2] [3] [4] [5]

15. I believe that the problems and difficulties with PWS environmental monitoring make the prediction of the expected environmental improvement difficult to assess.
Explanation: this question refers to the use of environmental monitoring data in simulation models to predict changes in environmental services under different conservation scenarios.
Important: in case there is no identified problems leave it blank.

[1] [2] [3] [4] [5]

16. From the following table of causes of problems, which ones do you consider to be the ones that have been affecting the most the monitoring systems of PWS projects?
Select ALL the options that apply.
[ ] lack of FUNDING/funds to maintain monitoring activities
[ ] lack of technical STAFF in the field
[ ] lack of LOGISTICS from the organizations in charge
[ ] lack of COOPERATION/synergies with public/private organizations
[ ] lack of technical CAPACITY of the organizations in charge
[ ] lack of WILLINGNESS from the organizations in charge
[ ] lack of perception of the NEED of monitoring from the organizations in charge
[ ] lack of SAFETY in the field
[ ] lack of access of adequate field INSTRUMENTS
[ ] lack of CALIBRATION of instruments
[ ] lack of field instrument MAINTENANCE
[ ] frequent DAMAGES on field instruments done by third parties
[ ] lack of local POLITICAL conditions
[ ] lack of ACCESS to monitoring points due to restrictions from property owners, government officials or companies
[ ] other. Specify in the final part dedicated to comments.

17. From the selected points above, please state the (1) first most important, (2) second most important, (3) third most important.

____

____

____

18. I believe it is important to communicate the results/impacts of conservation activities of the PWS projects (example: increase in water quantity/quality/regulation) to those who support/pay/donate to these projects.

[1] [2] [3] [4] [5]

19. Those who support/pay/donate to these PWS projects, in general, expect those in charge of the projects to demonstrate the environmental improvements obtained (example: increase in water quality/quantity/regulation).

[1] [2] [3] [4] [5]

20. Those who support/donate/pay for these PWS projects, in general, make the proof of environmental improvement achieved (example: increase in water quantity/quality/regulation) a condition for their financial support.

[1] [2] [3] [4] [5]

21. I believe that the evidence of the achieved environmental improvements in PWS projects (example: increase in water quantity/quality/regulation) is important for the reputation of the organizations that propose/manage these PWS projects.

[1] [2] [3] [4] [5]

22. I believe that the funds/donations to PWS projects made by PRIVATE companies have the following motivations:
* select all options that apply
[ ] expectation of improvement of environmental service quality/quantity/regulation for their own benefit/use
[ ] improvement of public-private relationships on local/regional level
[ ] improvement of the corporate image
[ ] corporate socio-environmental responsibility policy
[ ] environmental compensation required by law
[ ] others. In case you want, describe the motivation in the last part dedicated to comments.

23. I believe that the funds/donations to PWS projects made by PUBLIC companies have the following motivations:
* select all options that may apply
[ ] expectation of improvement of environmental service quality/quantity/regulation for their own benefit/use
[ ] improvement of public-private relationships on local/regional level
[ ] improvement of the corporate image
[ ] corporate socio-environmental responsibility policy
[ ] environmental compensation required by law
[ ] others. In case you want, describe the motivation in the last part dedicated to comments.

COMMENTS:
Please use the space below to make any comment/suggestion/detail that you may consider important or needed about any of the questions of this survey. In order to contact the person in charge of this survey, please drop an email to: leticia.lima@hu-berlin.de

Appendix II

Conservation Projects: Perceptions and motivations of the providers

Dear Sir./Madam, this questionnaire is part of a scientific research project that has the goal of evaluating the conservation projects that have been implemented in Colombia. This is part of a project supported by Humboldt-Universität zu Berlin, Germany, and Pontificia Universidad Javeriana, Bogota, Colombia.

This questionnaire in particular, was designed to get to know more and understand your point of view about the conservation project in which you are participating. We would like to hear your opinion and perspective about this project. The answers are anonymous, which means that they will not be presented alone nor identifying yourself. In order to get the most from this questionnaire, we would like to ask you to be as clear as possible in your answers. Thank you so much for your availability!

1. Location, date, project under evaluation, entity in charge of operating the project, questionnaire identifier:

<u>General Information about the respondent:</u>

2. How old are you, and how many years have you been living in this watershed/area?

3. Before living here, where did you live?

4. In which type of property do you live?
[ ] family property
[ ] inherited property
[ ] borrowed property
[ ] lease
[ ] occupation

5. Do you have kids? How many?

6. Where do your kids live? What do they do?
[ ] in the farm and study nearby
[ ] in the farm and work there
[ ] in the farm and work nearby
[ ] in the farm and work in another region
[ ] in another region and they study
[ ] in another region and they work
[ ] in another region and they are not studying/working
[ ] other (describe)

7. What is the size of your farm (hectares)?

8. What type of economic activity do you have in your farm?

[ ] cattle ranching
[ ] potatoes production
[ ] aquiculture (trout)
[ ] horticulture (vegetables in general) production
[ ] herbs production
[ ] fruit production
[ ] other (describe)
[ ] "I do not have an economic activity at my farm"

9. Since when are you engaged in this conservation project?

Motivations to enter the scheme:

There are different motives to participate in conservation projects. Some of them are more individual-driven and others are more collective-driven. Now we are going to talk about your personal reasons and motivations to participate in this project.

10. What were the initial motivations/reasons that led you to participate in this conservation project?

11. "I decided to enter the conservation project because..."
Select all motivations you had and then rank them by order of importance with a number beside the option check box: (1) the most important motivation; (2) the second most important one; (3) the third most important one. In case you have a motivation that is not listed, you can mention it in the box "Other".

[ ] I thought the project would improve the conditions for the productivity of my farm.
[ ] I thought the farm would look more organized/beautiful with the proposed interventions.
[ ] because with the new trees planted my cattle would have more shadow.
[ ] because my neighbors had joined the same project.
[ ] because I started to be concerned with water resources conservation.
[ ] because I like that people are concerned about our community
[ ] because I like the forest and wanted to have a bit in my farm.
[ ] because I believe that the project would improve water quantity/quality.
[ ] because I was already concerned about conservation before this project.
[ ] because in our community we are all interested in participate in environmental projects.
[ ] because the economic incentives caught my attention.
[ ] Other (describe).

Perceptions and expectations:

Now we are going to talk about certain important aspects among the objectives of the project and the perception of participants about them. Select among 1 to 5 how much you agree with the following statements. The scale of answers is gradual. For example: 1: totally disagree; ... 3: neither agree nor disagree; ... 5 total agree.

12. The conservation project will improve well the production conditions in my farm.

[1] [2] [3] [4] [5]

13. With the river fencing, my farm will look more organized/beautiful.

[1] [2] [3] [4] [5]

14. It is important that the landscape of our region is improved with the protection/recovery of forest cover.

[1] [2] [3] [4] [5]

15. It is important for the production that the cattle have more shadow by means of new planted trees.

[1] [2] [3] [4] [5]

16. I think that the compensation options and incentives that the project offer to us are good.

[1] [2] [3] [4] [5]

17. I felt motivated to participate in the scheme by the fact that other neighbors were already participating.

[1] [2] [3] [4] [5]

18. I like to see that there are people that are concerned about the environment and the economic productivity of our community.

[1] [2] [3] [4] [5]

19. Before this project I was not interested in the environmental activities such as water conservation interventions.

[1] [2] [3] [4] [5]

20. Water conservation has always interested me, even before this project.

[1] [2] [3] [4] [5]

21. The environment is important, but it is more important to obtain the benefits of the project for my farm.

[1] [2] [3] [4] [5]

22. I would have participated in any environmental activity and conservation even without economic benefits.

[1] [2] [3] [4] [5]

23. I would have participated in this project even without the material and economic incentives that I received.

[1] [2] [3] [4] [5]

24. There were good conservation projects before this one.

[1] [2] [3] [4] [5]

25. I trusted the previous conservation projects that were implemented here.

[1] [2] [3] [4] [5]

26. The operators of the current project have heard us and adapted the project according to the suggestions of our community.

[1] [2] [3] [4] [5]

27. Even though the incentives offered by the projects are interesting for our community, some of them do NOT seem to be useful.

[1] [2] [3] [4] [5]

28. This conservation project has accomplished ALL the expectations I had when I entered.

[1] [2] [3] [4] [5]

29. I trust the field staff of this project.

[1] [2] [3] [4] [5]

30. I noticed some changes in the water quality since the project started. (The water quality in this case may refer to the perception of color, smell, sediment amount or turbidity in the water).

[1] [2] [3] [4] [5]

31. There are still some years ahead until we can notice the desirable effects of this project regarding the water quality.

[1] [2] [3] [4] [5]

The Drought of 2015/2016:

Now we are going to talk about the drought that happened at the end of 2015 and beginning of 2016. Select among 1 to 5 how much you agree with the following statements. The scale of answers is gradual. For example: 1: totally disagree; ... 3: neither agree nor disagree; ... 5 total agree.

32. The droughts are frequent in this area.

[1] [2] [3] [4] [5]

33. During which months has the last drought happened?

[1] [2] [3] [4] [5]

34. There have been stronger droughts here in comparison to the one that we felt this year.

[1] [2] [3] [4] [5]

35. We had problems in our farm due to the last drought.

[1] [2] [3] [4] [5]

36. I needed to make some adaptations in my farm due to the drought.

[1] [2] [3] [4] [5]

37. The drought made me feel more conscious about the importance of conservation projects.

[1] [2] [3] [4] [5]

Appendix III

Questionnaire for donating/payer entities on PWS projects

Dear Sir./Madam, thank you for your time and dedication to this survey. Your collaboration contributes to science and conservation. We ask you to answer all questions, if possible. In case there is any question that you do not have an opinion to share, we ask you to leave the question without an answer. Your comments at the end of the questionnaire are very welcome. In order to secure the quality of the answers, please, take the time and concentration needed. The individual answers will remain anonymous in case this is the wish of the interviewed individual.

Pre-requisite: the interviewee (or the organization in which this person is employed) must be involved as donator/payer in processes of one or more Payment for Watershed Services projects, Compensation for water-related environmental service or Mechanisms to share benefits.

<u>General data about the payer</u>

1. The donating/payer entity is:
* Select just one option.
[ ] private company
[ ] government entity (example: ministry, autonomous corporations, regional authority, municipality, etc.)
[ ] public company
[ ] public-private company
[ ] civil association targeting socio-environmental issues
[ ] non-government organization / foundation / fund
[ ] multilateral organization / international cooperation
[ ] other. Specify in the last part dedicated to comments.

2. In case it is not important to keep your answers anonymous, we would be thankful if you could inform the name of the organization in which you are employed and the economic/institutional sector that the organization is related to.
____

3. Please, inform the name of your position/job at your organization:
____

4. What is your highest academic degree?
[ ] bachelors
[ ] specialization
[ ] masters
[ ] PhD
[ ] does not apply

5. What is your academic background? Example: economist, manager, biologist, geographer. Please, include your specialization/masters/PhD degree description.

____

6. What type of relation has the organization with a PWS scheme?
* select all that apply.
[ ] the organization acts as a payer/donator of a PWS scheme
[ ] the organization acts as intermediary/support/catalyzer of a PWS scheme
[ ] the organization acts as a fund raiser for a PWS scheme
* catalyzer means that the organization provides to get people together around the topic, incentivizing different actors to participate and potentially detecting and contacting additional payers for the scheme.

7. What type of support does the organization offer to a PWS scheme?
* select all that may apply.
[ ] funding / payment
[ ] provision of materials (example: technology, stationery, construction materials)
[ ] logistic services (example: room for meetings, food catering, transportation)
[ ] support for other types of services (example: documentation, photography, web design, construction, etc.)
[ ] technical support (example: monitoring/evaluation, agronomy, hydrologic analysis, GIS support)
[ ] other. Describe in the final part for comments.

8. In case the organization provides funds/payment in cash to a PWS scheme, with which frequency does it make the payments?
* select all that may apply.
[ ] a single initial payment
[ ] regular monthly payment
[ ] regular payment every 3 or 6 months
[ ] regular annual payment
[ ] punctual payment by means of specific projects
[ ] there is no payment in cash
[ ] other. Describe in the final part dedicated to comments.

9. For how long (in years) does the organization have the intention to provide funds to a PWS scheme?

____

10. Does the organization use water directly from the watershed where the funding/payments are applied?
[ ] yes
[ ] no
[ ] I do not know.

11. In case you answered yes in the previous question, to which end is the water used for?

[ ] public water supply. Example: by means of rural and urban aqueducts, groundwater wells, etc.
[ ] private water supply. Example: for pools, hotels, etc.
[ ] incorporated on the product. Example: agricultural products, cattle ranching, bottled water, beverages, food, etc.
[ ] used for industrial processes that do not include water in in the final product. Example: cleaning, air conditioning, dust reduction, heating, etc.
[ ] other. Describe in the final part dedicated to comments.

<u>Motivations from the organization acting as Payer</u>

In this part of the survey, we want to understand what has motivated yourself or your organization to fund/pay for a PWS scheme. We begin by asking about what types of environmental services are of importance for you and your organization.

12. How important for the organization is the water QUALITY of the watershed where funds are being applied?
* The scale of importance ranges from 1 (not important at all) to 5 (very important).

[1] [2] [3] [4] [5]

13. How important for the organization is the water QUANTITY of the watershed where funds are being applied?
* The scale of importance ranges from 1 (not important at all) to 5 (very important).

[1] [2] [3] [4] [5]

14. How important for the organization is the water REGULATION of the watershed where funds are being applied?
* The scale of importance ranges from 1 (not important at all) to 5 (very important).

[1] [2] [3] [4] [5]

15. Among the following environmental services, which ones are important for the organization?
* select all that apply.
[ ] maintenance/improvement of water QUALITY
[ ] maintenance/improvement of water QUANTITY
[ ] water provision in dry seasons / droughts
[ ] river discharge REGULATION during rainy seasons in order to avoid flooding
[ ] MAINTENANCE of forest cover for carbon sequestration
[ ] MAINTENANCE of landscape of touristic/aesthetic importance
[ ] MAINTENANCE of biodiversity
[ ] MAINTENANCE of fisheries
[ ] None of the options above.
[ ] other. Describe in the final part dedicated to comments.

16. From the selected environmental services, please, indicate an order of importance: (1) the most important, (2) the second most important, (3) the third most important.

____
____
____

17. Select all motivations that the organization or its representatives had to engage in a PWS scheme:
* Select all that apply.
[ ] ENVIRONMENTAL SERVICE improvement, meaning: water quality/quantity/regulation.
[ ] TAX DEDUCTION due to environmental causes
[ ] Environmental CERTIFICATION for its products or services
[ ] Environmental COMPENSATION required by law due to its productive activities
[ ] FUNDING REQUIRED BY LAW for the conservation of watersheds
[ ] Part of the process of environmental RESTORING in areas affected by the activities of the organization
[ ] Socio-environmental RESPONSIBILITY POLICY of the organization
[ ] Responsibility/MANDATE of the organization defined by law. Example: the case of regional autonomous corporations.
[ ] PUBLIC-PRIVATE RELATIONS improvement. Example: with the local communities.
[ ] Part of the mission of the organization. Example: the case of development banks/international cooperation.
[ ] SUSTAINABILITY INDEX from the stock exchange.
[ ] SHAREHOLDERS' requirements/demands
[ ] Part of an impact MITIGATION strategy in the production chain.
[ ] Environmental Services as part of the organization BUSINESS.
[ ] IMAGE of the organization. Green Marketing.
[ ] Investments in Environmental Services were already part of the TRADITION of the organization.
[ ] other.

18. If you has selected "other", please, indicate the motivation to which you refer:

____
____

19. Among the selected motivations, please, indicate in order of importance: (1) the most important, (2) the second most important, (3) the third most important.

____
____
____

20. Among the above motivations, which ones were NOT initial motivations but have been ultimately benefited the organization?

____
____
____

Perceptions of the Payer/Donating organization

In the following questions, we would like to know to which degree you agree with each of the statements. The scale is gradual, example: select 1 if you totally disagree, 3 if you do not agree not disagree, 5 if you totally agree.

21. The main motivation to engage in a PWS scheme was the need/expectation to improve the environmental service (quality/quantity/regulation of water).

[1] [2] [3] [4] [5]

22. The organization expects that the water quantity/quality/regulation will improve in the watershed by means of the conservation activities of the PWS scheme.

[1] [2] [3] [4] [5]

23. The organization believes that the PWS scheme will improve the water quality/quantity/regulation in the watershed by means of the conservation activities.

[1] [2] [3] [4] [5]

24. The organization requires a proof of the achieved environmental benefit as a condition for the payment to the PWS scheme.

[1] [2] [3] [4] [5]

25. In case the environmental benefits (improvement of water quality/quantity/regulation) of the PWS scheme are not proven over time, the organization would stop providing payments the PWS scheme.

[1] [2] [3] [4] [5]

Perception of the payer/donating organization regarding monitoring, control and evaluation

In this last part of the questionnaire, we aim at understanding how important it is to you and your organization the control and monitoring of conservation activities and the produced environmental benefits.

26. How important it is to the organization that the PWS managers regularly verifies the environmental results (in terms of water quality/quantity/regulation) of the PWS scheme through monitoring and evaluation of indicators?
* This is a gradual scale of importance that ranges from 1 (not important at all) to 5 (totally important).

[1] [2] [3] [4] [5]

27. The organization regularly requires monitoring and evaluation results of environmental indicators from the managers/practitioners of the PWS scheme.
* This is a gradual scale indicating degree of agreement with the statement. The options range from 1 (totally disagree) up to 5 (totally agree). Please select 3 in case you are not in agreement nor disagreement.

[1] [2] [3] [4] [5]

28. The organization ONLY requires monitoring/evaluation reports regarding conservation activities performed by the PWS practitioners and NOT regarding the achieved environmental benefits.
Example: a report about the implemented activities may include how many trees were planted or the number of benefited local families, but it would not include the impact of these activities over the environmental service.
* This is a gradual scale indicating degree of agreement with the statement. The options range from 1 (totally disagree) up to 5 (totally agree). Please select 3 in case you are not in agreement nor disagreement.

[1] [2] [3] [4] [5]

29. From the possible socio-environmental indicators/variables below, please indicate the ones that the organization requires monitoring and evaluation report to PWS managers:
[ ] increase in river/streams DISCHARGE
[ ] decreased amount of SEDIMENTS in rivers/streams
[ ] decreased amount of FERTILIZERS in the productive activities in the watershed
[ ] decreased amount of PESTICIDES in the productive activities in the watershed
[ ] reduced concentration of NITROGEN/PHOSPHOROUS in the water
[ ] improvement of water TURBIDITY
[ ] discharge REGULATED during dry seasons/droughts
[ ] discharge REGULATED during wet seasons/rainy seasons
[ ] total area of protected vegetation in the watershed
[ ] total area of vegetation under recovery in the watershed
[ ] number of planted TREES in the watershed
[ ] number of protected water SPRINGS
[ ] total extension of protected RIVER BORDERS
[ ] number of FAMILIES benefited by the conservation incentives
[ ] number of TRAINED INDIVIDUALS in environmental education/sustainable production
[ ] increase in family INCOME/poverty reduction of local communities in the watershed
[ ] other.

30. If you have selected “other” above, please describe it here.
____
____

31. Among the indicators/variables above, please, indicate in order of importance: (1) the most important, (2) the second most important, (3) the third most important.

____

____
____

32. Space dedicated to comments regarding the answers to this questionnaire.
* Please, include the number of the question to which your comment belongs. Thanks.
____
____
____
____

Selbständigkeitserklärung

Hiermit ekcläre ich, die vorliegende Dissertation selbstaständig und ohne Verwendung unerlaubter Hilfe angefertigt zu haben. Die aus fremden Quellen direkt oder indirekt übernommenen Inhalte sind als solche keentlich gemacht. Die Dissertation wird erstmalig und nur an der Humboldt-Universität zu Berlin eigereicht. Weiterhin erkläre ich, nicht bereits einen Doktortitel im Fach Geographie zu Besitzen. Die dem Verfahren zu Grunde liegende Promotionsordnung ist mir bekannt.

Letícia Santos de Lima
Berlin, 9. Oktober 2017