Doctoral Thesis

Decision-processes concerning the management of ecosystem services for ecosystem-based adaptation to climate change

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DECISION-PROCESSES CONCERNING THE MANAGEMENT OF ECOSYSTEM SERVICES FOR ECOSYSTEM-BASED ADAPTATION TO CLIMATE CHANGE

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presented by
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Summary

An increasing production of scientific literature addresses the past, current and future importance of ecosystems for the provision of goods and services to society. However, pressure from climate change, national policies and globalization are increasingly degrading this capacity of ecosystems. Typically, the design of societal responses to ecosystem services degradation requires considering the decision-making of multiple actors from the local scale where ES are provided to regional, national and international scales where decisions on rules and resources are defined and distributed. This is the case of SRS degradation which requires consideration of decision processes also considering the on- and off-site benefits of SRS. Indeed, soil erosion affects upstream land users and downstream user as hydropower dam due to siltation. Moreover, in a watershed, these actors directly benefiting from and making decisions regarding SRS are embedded in decision processes happening at scales that go beyond the watershed and beyond the direct use of SRS services (e.g., decisions to design technical solutions to soil erosion, decision on the provision of incentives and their types, etc.).

The goal of the thesis is to analyse the multi-hierarchy human decision processes characterizing SRS provision considering the human and environment system as two different, complementary and interrelated systems. In this thesis I analyse the case study of Soil Regulation Services (SRS) in the Birris watershed Costa Rica, a country pioneer in policies to protect ecosystem services. The Birris watershed is a relatively small territory with an area of 5800 has. It is characterized by intensive and market-oriented agricultural production activities with high fragmented farm areas and steep slopes. Soil erosion has been increasing since several decades due to inadequate land use practices and increasing extreme precipitation events whose intensity and frequency is expected to grow under climate change. The Birris watershed represents a learning case for many national and regional actors due to its commonality with other watersheds in the region.

The first of four articles of this thesis analyzes the environmental dimension focussing the role of forest ecosystem cover on hydrological responses. In the following three papers I address the human dimension focusing on decision processes occurring at different scales: i) from the individual farmers decision-making on soil conservation; ii) to the watershed scale where actors are directly affected by on-site and off-site provision of SRS; and, finally, iii) to the national cross-scale information-sharing network of multiple actors involved directly or indirectly (scientists,
regulators, farmers’ associations, users of SRS, etc.) in the management of watersheds and of SRS.

More specifically, the goal of the first paper is to synthesize the findings of several paired-catchment experiments from Africa, Asia and Latin America that analyze the effect of forest cover change on hydrological responses. We use meta-analysis as a tool used in ecological studies to synthesize results from different studies. This helps us overcoming the small “n” problem associated to many of these types of forest hydrology studies in watersheds especially in developing world.

The second paper addresses the complexity of farmers’ decision-making in respect to soil conservation decisions. This is analyzed through a multi-dimensional decision model including economic cognitive and territorial variables influencing farmers’ decision-making regarding soil conservation efforts. The structured survey included items built through previous meetings with farmers to capture their perspectives and understanding on soil erosion and its solutions.

The goal of the third paper is to analyze aspects that are relevant to build a collaborative mechanism among users of on-site and off-site provision of SRS. Specific methods from decision science and negotiation analysis are applied implying consultations with both users and providers of SRS. In separate meetings, consultations allowed structuring their fundamental objectives and identifying key aspects of composing a desired mechanism such as: i) how to select farmers; ii) what type of contract should be used; iii) who should intermediate and, finally, iii) the type of possible incentives for farmers’ soil conservation. In order to identify negotiation space for key aspects of a mechanism, preferences of both stakeholders in respect to different alternative aspects of a mechanism were elicited in two separate focus groups.

The goal of the fourth paper is to identify cross-scale institutional mismatches arising from formal policies and mandates and constraining SRS provision and use. We use “betweenness centrality” algorithm (common to social network science) to test how structural analysis of information-exchange network can identify boundary organizations which are potentially strategic to overcome cross-scale institutional mismatches. We analyze actors’ official mandates contributing directly or indirectly to SRS provision and their interaction in information-sharing network.

The analysis of the environmental dimension proves the usefulness and methodological limitations of using meta-analyses to synthesize findings from paired-catchments experiments
studies on the hydrological effects of changes in natural and planted forests cover. Overall results from experiments from Asia, Africa and Latin America show that forest cover can play an important role in diminish the base flow in watershed but its effect on storm-flow control (i.e. water runoff causing erosion) depends more on local characteristics. Some methodological limitations from this use of quantitative meta-analysis can also be outlined. We found a relatively small number of paired-catchment experiment studies from Asia, Africa and Latin America thus limiting the capacity to analyze the interacting effect of important factors for water flow regulation, such as soil, geology, topography, or land management practices. As for the capacity of forests to control storm flows (related to increase in erosion) data found in the scientific articles used in the meta-analysis did not allow accounting for the effects of frequent and intense extreme precipitation events. This also limits the capacity to compare the provision of SRS under climate change from natural forest ecosystem vs non-forest land uses such as conservation agriculture.

At the local scale, farmers’ awareness of their exposure level to soil erosion combines with other variables to determine their level of soil conservation efforts. The decision model includes socioeconomic, territorial and cognitive variables such as beliefs, values and risk perception and clearly separates three groups of farmers based on their soil conservation efforts. Most farmers are aware of the risk of erosion although socioeconomic aspects such as type of production and farm size indicate that perceived opportunity cost given the farm production context might hinder their conservation efforts. Farmers with low perception of erosion risk might also be expressing “availability heuristic” paradigm due to their daily experience with erosion in the watershed.

At the watershed scale, the design of collaborative efforts for the on- and off-site provision of SRS requires agreement on the fundamental objectives of a mechanism for collaborative efforts for soil conservation. Consulted farmers and hydropower agree on the importance of the promotion of learning through technical assistance and monitoring of soil conservation programs and the fair distribution of incentives. Direct payment for soil conservation is only limitedly considered as a desired incentive alternative. Consistent with the fundamental goal of promoting learning, technical assistance is seen as a more desirable alternative than direct payments.
The national cross-scale analysis of governance structure for SRS highlights that important regulatory mismatches affect the definition of societal responses at the local level (i.e. where direct actions to promote adequate provision and use of ES happen). Network analysis helps us identifying the information-bridging characteristics of actors in informal information-sharing networks. This analysis outlines the boundary role of the watershed agricultural-extension office helping diffusing information on impacts as well as social and technical feasibility of responses to SRS degradation across-scales and policy areas.

Overall the thesis’ results show that soil conservation policies to support the provision of SRS would benefit from the use of mixed policies. This might include programs to raise awareness on current and future soil erosion risks, promote learning among farmers, and institutionalize the boundary role of agricultural extension offices for their importance to promote learning and adaptive management of SRS. This is especially valuable in the context of areas highly exposed to increasing frequency of extreme precipitation events such as Central America. Moreover, in the face of high uncertainties and scarcity of data (e.g. on the impacts of land use/management and climate change), mechanisms to update and disseminate information over time on impacts on soil erosion and correspondent solutions are required. In this respect, strengthening the boundary role of agricultural-extension office can potentially help updating information available to scientists, regulators and farmers on impacts and social and technical feasibility of solutions. This might prove a strategy to address some of the regulatory mismatches that hinder responses to SRS degradation at local level and promote adaptive management of soil regulation services.
Zusammenfassung


Einzugsgebiet dient als Lernbeispiel für nationale und internationale Akteure, da es viele Gemeinsamkeiten mit anderen Einzugsgebieten aufweist.


Mechanismen zu identifizieren, wie beispielsweise: i) wie sollen die Bauern ausgewählt werden; ii) welche Kontakttypen sollten verwendet werden; iii) wer sollte Konflikte schlichten und schliesslich iv) welche Arten von Anreizen gibt es für Bauern für die Umsetzung von Bodenerhaltungsmassnahmen. Um die Verhandlungsspielräume für die Hauptaspekte des Mechanismus zu erkennen wurde mit jeder Akteursgruppe eine separate Fokusgruppe durchgeführt und die Präferenzen der Akteure zu verschiedenen alternativen Aspekten eines Mechanismus eruiert.


kontrollieren (welche zu erhöhter Erosion führen) erlaubten es nicht, die Effekte häufiger und intensiver Extremniederschläge zu berücksichtigen. Dies schränkt auch die Vergleichsmöglichkeit von der Bereitstellung von Bodenregulierungsdienstleistungen unter Klimawandel durch natürliche Waldökosysteme und nicht-Wald Landnutzungen wie beispielsweise Conservation Agriculture (Landwirtschaft mit konservierender Bodenbearbeitung), ein.


Die nationale ebenenübergreifende Analyse von Lenkungsstrukturen für Bodenregulierungsdienstleistungen betont, dass wichtige regulatorische Diskrepanzen lokale gesellschaftliche Reaktionen beeinflussen (d.h. da, wo direkte Handlungen zur ausreichenden Bereitstellung und die Nutzung von Ökosystems-Dienstleistungen stattfinden).

Mittels Netzwerkanalyse können wir die informationsüberbrückenden Charakteristiken von Akteuren in informellen Informationsaustausch-Netzwerken identifizieren. Diese Analyse streicht
die Schlüsselrolle von landwirtschaftlichen Beratungsbüros im Einzugsgebiet hervor, welche bei der Verbreitung von Informationen zu Umwelteinflüssen und technischer Umsetzbarkeit von Bodenschutzmassnahmen helfen, und dabei Informationen über Politikbereiche und Ebenen hinaus austauschen.

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1. Introduction

1.1 Relevance of soil erosion

Time needed to form soils is highly difficult to determinate although studies around the world suggest that, depending on specific interactions among climate, human and geological processes, up to hundreds of years might be required to develop soils (Chesworth, 2008). Soil fertility as well as its degradation due to erosion have been a strong driver of correspondingly civilization raise and decline (McNeill and Winiwarter, 2004). Currently, only less than one fifth of the earth’s land is potentially productive and available to provide 97 per cent of food supply (the rest from water systems). However, future food supply is bound to expand the intensification and frontiers of agriculture increasing erosion especially in marginal lands (Morgan, 2005). Evidence for this are suggested by the current rates of erosion in agricultural lands that are by large (i.e. between 13 and 40 times, Pimentel and Kounang, 1998) greater than natural soil production, soil loss under natural ecosystems and long-term-geological erosion (Montgomery, 2007).

High rates of erosion (from 20 to 100 t/ha/yr) are producing a decline in productivity as much as 15 to 30 per cent annually which corresponds (when considering the difficulty of restoring their fertility) to a loss of 6 million hectares annually (Pimentel et al., 1995). Around 85% of global agricultural land is affected by some form of degradation including erosion, salinization and compaction (WRI, 2000). According to UNEP’s Global Assessment of Soil Degradation (GLASOD), soil erosion accounts for 82 per cent of the human-induced land degradation thus affecting more than a billion hectares, although only 0.5% of which has reached an irreversible stage (Oldeman, 1992). These figures bear inherent uncertainty in their estimation for methodological reasons such as scaling up values from local assessments to large regional studies or using national evaluation standards instead of a unique global one. However, even considering uncertainties, they show that agricultural practices can reduce significantly soil erosion and provide food security as well as intermediate services to different sectors of society (e.g. water users, hydropower dams, carbon markets) (Morgan, 2005; Fisher et al., 2009).

In Latin America a major cause of soil degradation is associated to inappropriate soil management practices in agricultural land and in Mesoamerican Isthmus reaches 74% of croplands (Santibaniez y Santibaniez, 2007). Marginality of small landowners in steep lands and
intensification of agricultural production are important drivers of current soil erosion. Observed and projected frequencies of extreme precipitation events in Mesoamerica (Aguilar et al., 2005) indicate that climate change and variability are expected to exacerbate soil erosion and further affect soil productivity in agricultural lands. For this challenging contexts, Santibaniez and Santibaniez (2007) indicate that among the several adaptation options to reduce soil erosion in agricultural lands of Latin America improved information-sharing systems and innovative financial mechanisms are important. The former are necessary for early warnings against extreme climate as well as for increasing farmers’ knowledge on the implementation of sound soil management practices (Cash, 2001). Innovative financial mechanisms are also important to increase the capacity to access technologies and inputs for better soil management (Pagiola, 2008).

1.2 On- and off-site benefits of Soil Regulation Services (SRS)

The combined effect of upstream farmers’ decision regarding soil management and the increasing occurrence of extreme precipitation events determine the level of SRS provision both on-site and off-site. In this section I discuss the specific interaction of human and natural components defining the degradation of SRS as a result of soil erosion. More specifically, soil erosion can be defined as process including a detachment of soil particles and their transport by water or wind until energy is not sufficient and deposition occurs (Morgan, 2005). When considering the erosion control capacity of natural ecosystems, it is important to distinguish and to establish their relative importance and site-specific contributions to different types of erosion. Indeed, natural forest ecosystems tend to suffer relatively little surface erosion (Chomitz and Kumari, 1996) while they can contribute limitedly to control soil mass erosion (i.e. deeper than 3m) or in the recovery of soil structure from prolonged exposure to gully erosion. Throughout this thesis we use the term “soil erosion” to refer to surface erosion as produced by rain splash, overland flow and rill erosion which are influenced by soil, water and vegetation management practices farmers can decide to implement in their farms (Morgan, 2005).
The factors controlling soil erosion are the erosivity of the eroding agent (e.g. precipitation and wind), the erodibility of the soil (i.e. function of soil types\(^1\)), the slope of the land (e.g. its steepness, its shape and its length) and the nature of the plant cover and finally the energy of precipitation drops (Morgan, 2005). These factors interact with each other in a complex manner. For example, soil erodibility depends on interaction between geological and geomorphologic processes with site specific flora and fauna over hundreds of years (Chesworth, 2008) while the effect of precipitation and of vegetation cover can have immediate effects (e.g. dense vegetation cover can reduce soil erosion). Current societal decisions to define responses depend on awareness of these complex causal loops and on the contingent action-context of eroding agents. For example, precipitation erosivity (the most important soil particles-detaching agent; Morgan, 2005) is higher when bare unprotected soil surface is exposed to rain splash or runoff laminar erosion (Wischmeier and Smith, 1978). Farm level possible responses to soil laminar erosion can include measure such as management of vegetation cover, infiltration capacity and surface runoff kinetic potential or management of organic matter fostering soil structuration (Morgan, 2005). Society ideally should aim at achieving a rate of erosion control that equals that of new soil formation although where this balance lies for specific sites is unknown. Current annual average soil regeneration rate of world are 0.1 mm*yr\(^{-1}\) while soil erosion rates in some areas of the world are over 10 mm*yr\(^{-1}\) (Morgan, 2005). Farmers’ alternatives to reduce soil erosion include measures to contrast detachment phase of soil particles such as agronomic measures (e.g. managing vegetation cover) and soil management practices (e.g. ploughing with low impacts on soil structure). Mechanic methods (e.g. engineering management of slope topography or use of synthetic polymers, Orts et al., 2007) are instead directed to control the transport phase of soil particles. Agronomic measures are the most cost-effective and suitable to most farming systems (Morgan, 2005).

The scientific observation of erosion as well as its management must take into account whether both the on-site and off-site effects are considered or only one of them due to time-lags characterizing the transport of particles downstream. Indeed, while on-site effects of erosion can be both visible and perceivable in short-time horizon, its off-site effects on sedimentation

\(^1\) For example, volcanic soils such as Andosols are prone to heavy erosion in Central America since they lose physical structures due to their recent formation.
downstream must consider the characteristic time-lag between on-site removal of a soil particle and its off-site observation which tends to increase (due to increase of sediment storage areas) with the dimension of the catchment (Schoenholtz, 2004; Riedel et al., 2004). In specific sites where natural sediment production is low due to on-site natural equilibrium, forest clearing is bound to contribute to more erosion. Indeed, site- and species-specific relationship are important and natural forest should be seen as the natural baseline for erosion control against which all other land uses should be compared (Calder, 2002).

1.3 Soil erosion control: a human-environment paradigm

The analysis of soil erosion control requires considering complexity of actors and their decision-making, spatial and temporal scales and the interactions/feedbacks from action on the environment (i.e. soil) to its consequences on human activities. Since our goal is to understand how human (defined as the social system ranging from individuals to society) interacts with environmental system and what transition pathway can be outlined to improve management of soil resources, we can refer to the Human-Environment System (HES) paradigm (Scholz and Binder, 2004) as a framework allowing us to analyse this complex problem under a human-system perspective (i.e. to understand impacts of regulatory mechanisms inside a multi-hierarchy human system). Under this perspective, soil erosion control can be defined based on the decision-making that society needs to consider for their management (Fisher et al., 2009). According to these authors, classification of ecosystem services such as Soil Regulation Services must take into account the linkages among intermediate services such as soil formation, final services such as fertility provision and actual benefits which accrue when the beneficiaries actually is able to use these services to achieve their goals (e.g. producing agricultural products). The final achievement of beneficiaries’ intended goals using ecosystem services depends on other type of factors which condition the effective use of final services.\(^2\)

\(^2\) For example, hydropower production requires some built capital to harness the benefits of water regulation from upstream ecosystems
Then, under the decision-making perspective to study the provision and the use of ecosystem services such as soil erosion control we must consider on-site and off-site provision of this service and the corresponding actors interacting with the provision and/or use of this services. For example, on-site we must identify different actors/sectors playing different roles in the management and use of soil erosion control services according to whether they influence the provision of intermediate services (e.g. farmers influence the formation of soils while managing organic matter), the final service (e.g. which results from the interaction of soil characteristics and the specific on-site agricultural production type) and the actual benefit of producing agricultural products (e.g. which might be influences by farmers’ access to other inputs). On the other side, off-site benefits of soil erosion control services depend on the characteristics of the watershed dynamic transport of sediments downstream, on the specific requirements (e.g. hydropower dams needs low sediment load water) and capacity of a user to concretize its benefits.

Figure 1: Human-Environment System for soil erosion control in the Birris case study.
These on-site and off-site actors make decisions based on their goals but also on their access to resources coming from other actors that provide information on erosion control alternatives, on laws defining incentives for improved soil management, on the potential future threats to soil erosion, etc. Along with the general framework of HES, for the case of soil erosion control we need to consider a hierarchy of human systems from the individual farmers concerned basically with on-site access to SRS benefits, the downstream users of off-site SRS benefits, their mutual interest in the provision of SRS and the regulatory frameworks in which each of them is embedded as to guide legally their action, providing them with relevant information on alternative responses to SRS services degradation. Thus, goal formation and subsequent strategy formation to guide the transition (i.e. based on actors’ values; Keeney, 1992) depend on capability, experiences and constraints of individuals involved directly (e.g. farmers and hydropower downstream users of SRS) or indirectly (e.g. regulators, scientists providing information on alternative technically-feasible responses) in the problem of SRS degradation. Environmental awareness (i.e. of impacts, of externalities) represents the interface of the human-environment system \((H \cap E)\) where individuals according to their mental model of the environment define what are direct and short-term consequences of their actions on the environment and what are delayed effects. In the specific case of soil erosion control services farmers and downstream SRS users normally have a direct a short-term experience of environmental consequences of soil management actions. However, the specific environmental context of SRS intrinsically includes longer-term environmental consequences of human actions. For example, soil formation in volcanic soils might provide deep soils where the effects of top-soil losses due to erosion might not be visible or experienced in the short-term productive cycle of the direct users of SRS. It might require longer time until the consequences are evident. Similarly, climate change and variability can worsen the environmental consequences of soil management actions in the longer term which might not be evident or considered in day to day decision-making of actors (Sivakumar and Ndiangui, 2007). In this case, actors depend also on access to scientific information that improves their understanding of short and longer-term consequences of their actions as well on the design of alternative regulatory that allow involved actors to respond and adapt over time to changing conditions (Duit and Galaz, 2008). The proposed HES (Scholz and Binder, 2004) provides an interesting framework signalling
that the environmental consequences of human action at one scale (e.g. at the farm level) need supportive actions at a scale different from that of the action (e.g. at the national or watershed scale designing new research on technology options and technology-transfer mechanisms, designing new regulatory incentives for sustainable soil management, etc.).

In this respect, awareness of environmental consequences of human action in the context of SRS services is relevant not only among those who are directly dealing with SRS degradation (i.e. providers and users of SRS) but also among those who influence regulations, incentives and scientific understanding on SRS. Along with the HES paradigm, these actors’ awareness of SEC degradation and/or of their corresponding role potentially influence their decision-making and can thus condition the constraints and opportunities that directly-interested actors face to cope with this environmental problem. This specific principle of the HES paradigm is especially relevant since the complexity and deep-uncertainty (Hulme, 2005) of the combined effects of climate change and soil management practices on SRS need updating information over time to adjust actions undertaken. In other words, regulatory, incentive and science production mechanisms that allow human system to establish adaptive cycles are extremely important to cope with changing conditions (i.e. change in frequency and intensity of extreme precipitation events) that are by a large part unknown (Cash et al., 2003; Duit and Galaz, 2008).

1.4 Purpose and research questions of the thesis

The objective of this study is to contribute to understanding of the human dimension of soil degradation problem using a multi-scale approach. Our research questions arise from the analysis of the factors that characterize soil erosion control. We thus consider the environmental system by analysing multiple studies on forest cover change-water services relationship (i.e. through meta-analysis. On the human dimension we take into account the multi-scale characteristics of soil erosion by approaching the different decision contexts that at each scale are relevant. In this respect, farmers’ decision-making regarding their farm-soils accounts for decisions that have the most direct impacts of humans on the soil resource. At the watershed scale and using an ecosystem service approach we analyse the aspects that upstream providers of Soil Regulation Services (i.e. farmers) and downstream users of SRS (i.e. hydropower dam) consider important to
establish a collaborative effort (i.e. through negotiation analysis) to improve on-site and off-site SRS provision. Finally, we analyse the cross-scale interaction of actors from different policy areas (e.g. regulators, scientists, NGOs, farmers’ associations, etc.) in information-exchange and multiple formal-policy objectives contexts. An additional article has been included to report the perspective of more than 80 experts on ecosystem-based adaptation to climate change from different disciplines in Latin America. Key messages from these experts support the importance of communication and information-sharing mechanisms as well outline the need for intermediary organization bridging different knowledge-communities from the local to national scale.

1.5 Meta-analysis of forest-cover change effects on water-related ecosystem services

Society has, since long, taken for granted the beneficiary role of forest cover in providing water-related ecosystem services (Andreassian, 2004). General rule of thumb on the role of forest ecosystems in providing water-related ecosystem services is hindered by high site-specificity of this relationship. More important for the thesis’ focus on SRS, it is important to look at the effect of forest cover on hydrological processes such as storm flow that can cause soil erosion. We use meta-analysis (Gurevitch et al., 2001) to run a quantitative synthesis of the findings of studies from different sites around the world. The limited number of studies on the specific relation forest cover-water runoff and erosion hinder the benefits of using meta-analysis to draw general conclusions (Ilstedt et al., 2007). We thus concentrate on studies that include analysis of the effects of forest cover on hydrological responses such as storm flow (defined as a part of water runoff; UNESCO-WMO, 1992) which is a proxy of soil erosion (Bonell, 1998).

Research question: Can quantitative meta-analysis help resolve the small “n” problem affecting decisions regarding the role of forest ecosystems in providing water-related services? Can this method help making general conclusions and so guide policy making on soil cover management?

1.6 Farmers’ decision model regarding soil conservation effort

Many studies of adoption of control erosion measures by farmers have been based on assumptions derived from neo-classical economics (Van de Bergh et al., 2000). However, evidences suggest that decision making of farmers is a complex combination of site-characteristics and other cognitive aspects. This is especially relevant considering that observable
effects of soil erosion are not perceived equally among farmers and among higher and lower soil erosion risk areas.

Research question: Do risk perception, values and beliefs influence farmers’ soil conservation behaviour or it is only economic reasoning that guide farmers’ behaviour?

1.7 Two-party negotiation analysis for a mechanism to promote Soil Regulation Services

Collaborative planning for complex human-natural systems necessarily relies on negotiation (Innes and Booher, 1999); yet how to structure negotiations for protection of ecosystem services has received little attention in literature. Collaborative efforts among providers and users of SRS are complex given the multiple objectives, mandates and perceptions characterizing involved actors. Our research questions refer to whether two-party negotiation analysis can prove useful in highlighting parties’ objectives and whether structuring them in a formal template can identify shared decision spaces which might be relevant for building future collaboration.

Research question: Can negotiation analysis help structuring the multiple objectives characterizing ecosystem service providers and users? What characterizes the negotiation space for a mechanism to protect Soil Regulation Services among providers and users of SRS?

1.8 Institutional mismatches and information-sharing in multi-actors’ and cross-scale governance for Soil Regulation Services

Mandates, actions and interactions of multiple actors at different scales and from different knowledge systems directly or indirectly constrain or promote the decisions of local actors affecting on-site and off-site SRS provision (Cash and Moser, 2000). This complex multi-actor governance system provides potentials or barriers to improve societal response to SRS degradation under climate change. We analyse multiple formal policy mandates as described by formally stated/published objectives (e.g. in laws, decrees, etc.) to identify institutional mismatches and opportunities for enhancing societal capacity to respond. Additionally, we test the use of formal governance network analysis to identify key organization that can play the important boundary role needed to bridge different scales and knowledge systems required to face SRS degradation.
Research questions: What are main institutional mismatches that pose barriers to collective action in large governance network? Can formal structural analysis of governance network identify key organizations to play boundary role in such network and thus help overcoming institutional mismatches?

1.9 Goals and justification of the methods used

Following the human-environment system perspective in the following paragraphs, the methods we used helped us characterizing environmental characteristics of the provision of watershed services and, for the human system, approaching the different decision processes at specific scale of analysis. I here provide some additional rationale for the methods used, sending the reader to each specific chapter for further details on the methods used.

First paper status: published
A challenge facing managers and decision makers is the complexity of the effect of forest ecosystems on water flows also due to limited availability of large-n studies across sites to detect important trends in this relationship. Meta-analysis is a statistical technique for combining the quantitative findings of several studies and provides a conclusive synthesis of the main effects of a treatment. This technique has seldom been used in the study of water-related ecosystem services (Ilstedt et al., 2007).
The goal of the first paper was to test the usefulness of quantitative meta-analysis in summarizing the findings of several studies that considered the role forest cover change in the provision of watershed services. The main expected benefit of this research is to overcome the small “n” problem associated to many of these types of studies given the high cost of running the required experiments (e.g. changing forest cover) in watersheds especially in tropical areas.

Second paper status: published

The second paper addresses the complexity of farmers’ decision-making in respect to soil conservation decisions. We test the hypothesis on the influence of cognitive and territorial variables (along with commonly-used economic variables) on individual farmers’ decision-making regarding soil conservation. To prepare the structured survey instrument we did not pre-define the items and multiple response options. Instead, we built some of the items and the correspondent multiple choice options through previous meetings where we elicited participants’ perspectives and understanding on soil erosion and its solutions.

**Third paper status:** second round revision in Ecological Economics

Vignola, R., McDaniels, T.M., Scholz, R.W., 2010. Negotiation analysis for mechanisms to deliver ecosystem services: a value-focused bargaining structure to achieve joint gains in the provision of Soil Regulation Services. Submitted to Ecological Economics.

The goal of the third paper was to analyze what aspects are relevant to providers and users of SRS in the specific case-study watershed. We approach this by using specific methods from decision science (e.g. structuring means-ends objectives; Keeney, 1992) and negotiation analysis (e.g. template building; Raiffa et al., 2002). In the context of watershed services providers and users of SRS are separated administratively and geographically and might not know they could improve their gains by collaborating. Moreover, how to structure this collaboration is not obvious. In this respect, the methods used implied consultations with stakeholders to structure their fundamental objectives and identify key aspects that alternatives should include. This helped us building a stakeholders’ salient negotiation-framework including a set of alternatives to elicit their preferences.

**Fourth paper status: submitted**


In the last paper, the goal is to identify institutional mismatches arising from formal policies and mandates and constraining SRS provision and use. On the other side, we test how structural
analysis of information-exchange network can help identify boundary organizations that might help overcome these institutional mismatches. Actors in the governance network have each their own official mandate by law or consensus and contribute directly or indirectly to SRS provision through their specific role (e.g. funding, science, regulation, support to farmers, etc.). To characterize this formal policy framework it is necessary to recompile laws, text in web pages stating official mandates and organization’s corporate communication documents. To analyse the informal interaction in information-sharing network, interviews to actors are required in order to let them indicate with whom their interchange information and elicit their views on how other organizations in the network produce trustable information and influence relevant policy processes.

1.10 References


Bonell, M., Possible impacts of climate variability and change on tropical forest hydrology. Climatic Change 39, 215-272


2. Managing watershed services of tropical forests and plantations: can meta-analyses help?


Abstract
The watershed services provided by tropical natural and planted forests are critical to human well-being. An increasing number of valuation studies and experiences with payment for ecosystem services have dealt with the role of ecosystems in regulating the flow of water. However, several studies have been based on misconceptions about the role of forests and plantations in the hydrological cycle, despite the publication of many reviews by hydrologists. The objective of this paper is to evaluate whether meta-analyses applied to studies comparing water flows in tropical watersheds under natural or planted forests and non-forest lands can provide useful results for valuing watershed ecosystem services and making decisions. The meta-analyses show significantly lower total flows or base flows under planted forests than non-forest land uses. Meta-analyses conducted with subsamples of the data also show lower total flow and higher base flow under natural forests than non-forest land uses. However, the available studies were restricted to humid climates and particular forest types (Pinus and Eucalyptus planted forests and lowland natural forests). The small number of available studies with sufficient original data is a major constraint in the application of meta-analyses. This represents a major technical challenge for valuation studies or payment for ecosystem services, especially in countries where financial resources for implementing field research are scarce.

Keywords: ecosystem services; tropics; natural forest; planted forests; hydrology; policy; meta-analysis

2.1 Introduction

Ecosystems provide services critical to human well-being, in particular watershed services that regulate the quantity of water available for human activities. The conservation of dry season stream flows is essential for navigation, recreation, wildlife, and for rural communities, as well as for irrigation systems that lack the technology for pumping groundwater (Aylward, 2005). The reduction of storm flow may benefit housing, infrastructure, or agriculture in flood-prone areas.
The conservation of total annual water flow is also relevant to reservoirs for drinking water or hydroelectricity production (Guo et al., 2000).

Over the past 50 years, however, the conversion of natural ecosystems to other land uses has dramatically altered hydrological cycles (Millennium Ecosystem Assessment, 2005). The combined effects of climate and land cover changes require societies to adopt appropriate adaptation measures for reducing their vulnerability to water scarcity and excess (Oki et al., 2006; Hulme, 2005). These measures should include the protection or restoration of ecosystems providing watershed services, especially in developing countries with low technical and financial capacity to regulate water flows with engineered solutions (Bergkamp et al., 2003; Pattanayak, 2004). In this respect, financial mechanisms that encourage the provision of ecosystem services, such as payments for ecosystem services (PES), are increasingly being used to manage upstream forest ecosystems for the regulation of water flows (Wunder, 2005; FAO, 2004; Dudley et al., 2003).

Valuation studies of watershed ecosystem services and management or policy decisions about PES are not always scientifically sound. Various misconceptions about the role of ecosystems in regulating the flow of water persist among managers and decision-makers, despite the publication of many scientific papers on this issue (e.g., Bosch and Hewlett, 1982; Bruijnzeel, 1990; Critchley and Bruijnzeel, 1996; Sahin and Hall, 1996; Bonell, 1998; Calder, 2002; Best et al., 2003; Andreassian, 2004; Bruijnzeel, 2004; Scott et al., 2004; Bonell and Bruijnzeel, 2005; Farley et al., 2005; Guillemette et al., 2005; Scott et al., 2005). A challenge facing managers and decision-makers is the complexity of the effect of ecosystems on water flows (Bruijnzeel, 1990; Fujieda et al. 1997; Bonell, 1998; van Noordwijk et al., 2004; Waage et al., 2008).

Meta-analysis, a statistical technique for combining the quantitative findings of several studies, has seldom been used in forest hydrology (Ilstedt et al., 2007). Meta-analysis has the ability to consider several studies that are in themselves inconclusive, and provide a statistically conclusive synthesis. Although it requires simplification of the observed phenomena, meta-analysis has the advantage of producing results that are more easily understandable by decision-makers than narrative reviews. The objective of this paper is to evaluate whether meta-analyses applied to studies comparing water flows in tropical watersheds under different forest or non-forest covers
can provide useful results for valuing watershed ecosystem services and making decisions about PES and watershed management.

2.2 Method

We conducted several meta-analyses to combine the findings of studies comparing water flows between watersheds under natural forests vs. non-forest land uses, and planted forests vs. non-forest land uses. These studies were synchronic comparisons of two or more paired watersheds or diachronic comparisons of one watershed under changing forest cover over time. We considered natural and planted forests because both are being considered in PES for watersheds (Wunder et al., 2008). For instance, the national PES scheme in Costa Rica rewards forest conservation and plantation and recognizes explicitly hydrological services, including the provision of water for human consumption, irrigation, and energy production (Pagiola, 2008).

We considered three hydrological variables of interest: annual total flow, storm flow, and base flow. According to the Glossary of Hydrology of UNESCO-WMO (1992), annual total flow is the “total volume of water that flows during a year, usually referring to the outflow of a drainage area or river basin”. Storm flow is “part of surface runoff which reaches the catchment outlet shortly after the rain starts; its volume is equal to rainfall excess”. Base flow is the “part of the discharge (volume of water flowing through a river or channel cross-section in unit time) which enters a stream channel from groundwater from lakes and glaciers during long periods when no precipitation or snowmelt occurs” (UNESCO-WMO, 1992). Other authors have modified this definition by adding that base flow is “the more or less permanent flow supplied to drainage channels by rather invariable sources” (Susswein et al., 2001). In areas with seasonality in rainfall, the discharge during most of the dry season results from base flow (Smakhtin, 2001).

We followed the generally accepted procedures for meta-analysis (e.g., Cooper and Hedges, 1994; Gurevitch et al., 2001). First, we searched peer-reviewed articles comparing water flows under natural or planted forests and non-forest land uses in tropical watersheds. We searched references in CAB, ISI Web of Science, and the AGRICOLA literature database in March 2006 with the following query: “(forest OR deforestation OR reforestation OR afforestation) AND (water OR hydrology OR hydrological) AND (watershed OR catchment OR land use OR land-use) AND (tropical OR subtropical)”. About 1100 references were retrieved.
Second, we selected studies conducted in whole watersheds (i.e., not in plots) that compared several watersheds under different land-uses during several years or one catchment during several years before and after a land-use change. We selected only studies reporting field measurements (i.e., not modeling results) and providing “sufficient data”. By “sufficient data”, we mean that the studies reported one of the following data combinations: (1) annual values of a hydrological variable for each watershed and each year, or (2) means and standard deviations of a hydrological variable and the number of observations for watersheds under forests and non-forest land uses. This selection resulted in only 10 studies. To ensure a larger sample, we searched for documents cited by review articles that complied with our selection criteria, and retrieved 10 more studies. We characterized the studies according to forest type (planted vs. natural forests), watershed area, humidity index, and forest cover difference. Data about the humidity index, defined as the ratio of annual precipitation and potential evapotranspiration, came from Deichmann and Eklundh (1991). Forest cover difference was defined as the difference in forest cover between the compared watersheds, and was considered to be high if it was more than 50% of the watershed area.

Third, each comparison (i.e. comparison of one hydrological variable between different watersheds) found in the selected studies was converted to a dimensionless scale called the effect size. We chose the Hedge's unbiased estimator $g$ of effect size, and used equations described by Cooper and Hedges (1994) to estimate the effect size and its variance for each comparison. Fourth, we combined the estimates of effect sizes using a random effect model that considers a random variation among the studies in the "true" effect (Gurevitch et al., 2001; Shadish and Hoaddock, 1994). We conducted six meta-analyses for each of the three hydrological variables of interest and for natural and planted forests. We also applied meta-analyses to subsets of the data, e.g., only small watersheds. Finally, for each meta-analysis, we conducted a sensitivity analysis to determine whether some individual comparisons influenced the results, by performing $n$ partial meta-analyses ($n$ being the number of comparisons) on data sub-samples containing all the comparisons but the $n^{th}$ one. Only significant differences (at $p < 0.05$) observed in a meta-analysis and all associated partial meta-analyses were reported. We considered that the tendency to report only significant results – or the "file drawer problem" (Fernandez-Duque
and Valeggia, 1994) - was not a relevant bias in our analysis, because the results of costly long-term hydrological studies are generally reported even if no significant differences are found.

2.3 Results and discussion

2.3.1 Selected studies

Among the 20 selected studies, nine were conducted in Asia, eight in Africa, and three in Latin America (see Table 1 for details of the studies, and Figure 1 for their location). The small number of studies is due to the lack of comparison between watersheds under forests and non-forest land uses and the lack of sufficient data in many studies. The focus of the meta-analyses on tropical areas, the theme of this special issue of Forest Ecology and Management, also strongly reduced the number of available studies, as tropical areas are under-represented in the scientific literature about forest hydrology. For example, among 135 watershed experiments reviewed in Andreassian (2004), only 16 are tropical watersheds.
Table 1. Characteristics of the selected studies.

<table>
<thead>
<tr>
<th>First author and year</th>
<th>Country</th>
<th>Humidity class (2)</th>
<th>Watershed area (3)</th>
<th>Forest cover difference (4)</th>
<th>Years (5)</th>
<th>Description (6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bailly 1974p(1)</td>
<td>Madagascar</td>
<td>HU</td>
<td>S</td>
<td>Hi</td>
<td>64-71</td>
<td>NF Syn (4 w. forest, 2 w. agriculture/fallow)</td>
</tr>
<tr>
<td>Bailly 1974m</td>
<td>Madagascar</td>
<td>HU</td>
<td>S</td>
<td>Hi</td>
<td>62-72</td>
<td>PF Syn (1 w. Eucalyptus, 2 w. agriculture/fallow)</td>
</tr>
<tr>
<td>Bewket 2005</td>
<td>Ethiopia</td>
<td>HU</td>
<td>L</td>
<td>Lo</td>
<td>60-64 and 80-84</td>
<td>NF Dia (1 w. less forested in 1960 than in 1982).</td>
</tr>
<tr>
<td>Blackie 1972</td>
<td>Kenya</td>
<td>HU-DR</td>
<td>L</td>
<td>Hi</td>
<td>61-68</td>
<td>NF Syn (1 w. forest, 1 w. partially agriculture)</td>
</tr>
<tr>
<td>Chandler 1998</td>
<td>The Philippines</td>
<td>HU</td>
<td>S</td>
<td>Hi</td>
<td>95-96</td>
<td>NF Syn (1 w. forest, 2 w. grasslands)</td>
</tr>
<tr>
<td>Costa 2003</td>
<td>Brazil</td>
<td>HU</td>
<td>L</td>
<td>Lo</td>
<td>49-68 and 79-98</td>
<td>NF Dia (1 w. less forested in 49-68 than in 79-98).</td>
</tr>
<tr>
<td>Dagg 1965</td>
<td>Tanzania</td>
<td>HU</td>
<td>S</td>
<td>Hi</td>
<td>57-63</td>
<td>NF Syn (1 w. forest, 1 w. agriculture)</td>
</tr>
<tr>
<td>Fritsch 1983</td>
<td>French Guyana</td>
<td>HU</td>
<td>S</td>
<td>Hi</td>
<td>77-81</td>
<td>NF Syn (2 w. forest, 6 w. deforested/pasture)</td>
</tr>
<tr>
<td>Fritsch 1992</td>
<td>French Guyana</td>
<td>HU</td>
<td>S</td>
<td>Hi</td>
<td>77-87</td>
<td>NF Syn (2 w. forest, 2 w. pasture/slash-and-burn)</td>
</tr>
<tr>
<td>Goujon 1968</td>
<td>Madagascar</td>
<td>HU</td>
<td>S</td>
<td>Hi</td>
<td>62-66</td>
<td>PF Syn (1 w. Pinus, 1 w. grassland)</td>
</tr>
<tr>
<td>Lal 1997</td>
<td>Nigeria</td>
<td>HU-DR</td>
<td>S</td>
<td>Hi</td>
<td>74-75 and 79-84</td>
<td>NF Dia (1 w. deforested in 1979)</td>
</tr>
<tr>
<td>Mathur 1976</td>
<td>India</td>
<td>DR</td>
<td>S</td>
<td>Hi</td>
<td>61-67 and 69-73</td>
<td>PF Syn (after 1969 1 w. Eucalyptus, 1 w. shrub)</td>
</tr>
<tr>
<td>Mungai 2004</td>
<td>Sri Lanka</td>
<td>HU</td>
<td>L</td>
<td>Lo</td>
<td>51-61, 67-77, 78-88</td>
<td>NF Dia (1 w. under deforestation)</td>
</tr>
<tr>
<td>Mwendera 1994</td>
<td>Malawi</td>
<td>HU</td>
<td>L</td>
<td>Hi</td>
<td>61-65, 70-78</td>
<td>PF Dia (1 w. forestation with Pinus and Eucalyptus)</td>
</tr>
<tr>
<td>Raghunath 1970</td>
<td>India</td>
<td>HU</td>
<td>L</td>
<td>Hi</td>
<td>Various periods</td>
<td>NF Syn (9 w. mainly under agriculture or pasture, 3 w. mainly under forest)</td>
</tr>
<tr>
<td>Samraj 1988; Sha</td>
<td>India</td>
<td>HU</td>
<td>S</td>
<td>Hi</td>
<td>68-71, 73-81, 82-91</td>
<td>PF Syn (after 1972 1 w. Eucalyptus, 1 w. shrub)</td>
</tr>
<tr>
<td>Sikka 2003</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PF Dia (1 w. under shrub before 1972, then Eucalyptus)</td>
</tr>
<tr>
<td>Wilk 2001</td>
<td>Thailand</td>
<td>HU</td>
<td>L</td>
<td>Hi</td>
<td>57-64, 87-94</td>
<td>NF Dia (1 w. with decreasing forest cover)</td>
</tr>
<tr>
<td>Zhou 2002</td>
<td>China</td>
<td>HU</td>
<td>S</td>
<td>Hi</td>
<td>81-90</td>
<td>PF Syn (1 w. Eucalyptus, 1 w. bare soil)</td>
</tr>
</tbody>
</table>
Two studies are reported in the same reference (Bailly et al., 1974), one in Périnet (1974p) and another in Manankazo (1974m).

(2) HU=humid area, HU-DR= humid area near the transition between humid and dry (less than 50km), DR=dry area. Humidity index taken from Deichmann and Eklundh (1991).

(3) S=Small (< 1 km²), L=Large (> 1 km²).

(4) Lo: forest cover differs by less than 50% of the watershed area between the compared watersheds, Hi: more than 50%.

(5) Period(s) of time selected for our analysis.


Among the 20 studies, 13 studies were conducted in watersheds smaller than 1 km² and seven in watersheds larger than 1 km². Seventeen studies compared watersheds with high forest cover difference (more than 50% of the watershed area). Seventeen studies were conducted in humid areas, and three in dry areas or transition areas between humid and dry. This result shows a bias in the meta-analyses, as no studies in semi-arid or arid areas and few studies in dry areas provided sufficient data. As the results cannot be generalized to the tropics as a whole, the scientific knowledge for decision making in dry, semi-arid, and arid areas is lacking.

Figure 1. Location of the 20 studies selected for the meta-analyses.

In the 20 studies, we retrieved 63 comparisons between watersheds under natural or planted forests and non-forest land uses. On average, a comparison was based on 16 observations (e.g., one watershed observed during 16 years or four watersheds during four years). The numbers of studies and comparisons are within the acceptable range of sample sizes used in other meta-analyses. Indeed, in the few meta-analyses that have been applied to hydrology, the sample sizes were generally lower; for instance, 14 observations and four studies in Ilstedt et al. (2007).
2.3.2 Natural forests

In 12 of the 20 selected studies, 39 comparisons were analyzed between watersheds under natural forests and non-forest land uses. These comparisons were related mostly to watersheds larger than 1 km$^2$ (26 comparisons), with high forest cover differences (24), and in humid areas (36). No studies about montane cloud forests complied with our selection criteria. As these forests can have a different effect on water flows compared to other natural forests because of their capacity to collect water from the clouds, valuation of ecosystem services or decision making about cloud forests should not be based on our meta-analyses.

Including all comparisons, the meta-analysis did not show significant differences in total flow between watersheds under natural forests and non-forest land uses (see Table 2). However, when selecting comparisons made in small watersheds or large differences in forest cover, the meta-analyses showed that the total flow was significantly lower in watersheds under natural forests than non-forest land uses. This result shows the interest in comparing small watersheds or watersheds with large differences in forest cover. Some authors have stated that the effects of forests on water flows are discernable only in watersheds smaller than 1000 km$^2$ (FAO and CIFOR, 2005) or 500 km$^2$ (Pattanayak, 2004), while others have stated that the most significant observations have been made in small watersheds, usually less than one km$^2$ (Bruijnzeel, 2004). Separating the hydrological effects of forests is more difficult in larger catchments, which generally present diverse land uses and land-use changes.
Table 2. Results of the meta-analyses.

<table>
<thead>
<tr>
<th>Results of the meta-analysis with all data</th>
<th>Selected studies (i)</th>
<th>Number of comparisons and characteristics of the compared watersheds (ii)</th>
<th>Other significant results of the meta-analyses with data subsets (ii)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Differences in flows between natural forests vs. non-forest land uses (Studies available only for lowland forests. No studies on cloud forests).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total flow: No significant difference</td>
<td>11 (Bai74p Bew05 Bla72 Cha98 Cos03 Dag65 Fri83 Lal97 Mun04 Rag70 Wil01)</td>
<td>15 (6 small w, 9 large w, 1 dry, 12 humid, 2 11 high 3 diff., 4 low diff)</td>
<td>With small w. or high diff.: Less total flow in natural forest than non-forest land uses</td>
</tr>
<tr>
<td>Base flow: No significant difference</td>
<td>4 (Bai74p Bew05 Mun04 Wil01)</td>
<td>8 (1 small w, 7 large w, 8 humid, 2 high diff., 6 low diff.)</td>
<td>In large w.: More base flow in natural forest than non-forest land uses</td>
</tr>
<tr>
<td>Storm flow: No significant difference</td>
<td>8 (Bai74p Bew05 Cha98 Cos03 Fri92 Mun04 Rag70 Wil01)</td>
<td>16 (6 small w, 10 large w, 16 humid, 9 high diff., 7 low diff.)</td>
<td>None</td>
</tr>
<tr>
<td>Differences in flows between planted forests vs. non-forest cover (Studies available only about Eucalyptus and Pinus plantations. No studies on other species, incl. native species).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total flow: Less total flow in planted forest than non-forest land uses</td>
<td>7 (Bai74m Bai74p Gou68 Mat76 Sam88 Sha98 Zho02)</td>
<td>11 (11 small w, 1 dry, 10 humid, 11 high diff.)</td>
<td>With small w., humid or high diff.: Same result</td>
</tr>
<tr>
<td>Base flow: Less base flow in planted forest than non-forest land uses</td>
<td>5 (Bai74p Mwe94 Sam88 Sha98 Sik03)</td>
<td>8 (7 small w, 1 large w, 8 humid, 8 high forest diff.)</td>
<td>With small w., humid or high diff.: Same result</td>
</tr>
<tr>
<td>Storm flow: No significant difference</td>
<td>5 (Bai74p Gou68 Mwe94 Sam88 Sha98)</td>
<td>4 (4 small w, 1 large w, 5 5 humid, 5 high diff.) 7</td>
<td>None</td>
</tr>
</tbody>
</table>

(vii) Number of studies and references in parenthesis (references are given with the first three letters of the first author’s name and the 2-digit year).

(viii) “small w.” = watershed smaller than 1 km², “large w.” = watershed larger than 1 km², “humid” = humid according to Table 1 definition, “dry” = dry or transition from humid to dry, “low diff.”= forest cover differs by less than 50% of the watershed area between the compared watersheds, “high diff.”= more than 50%.

The effect of natural forests on total flow has been demonstrated by other authors in diverse situations, although they may not be valid for some very old forests or cloud forests (Calder, 2002; Bruijnzeel et al., 2004). These effects can be explained by the higher evapotranspiration rates in forests compared to pasture or annual cropping land uses (Bruijnzeel, 1990). Trees with deep roots and high transpiration rates may act as pumps that remove water from the soil and transpire it. Although conversion of natural forests to non-forest land uses is immediately followed by a period of increased total flow, the subsequent period may not be characterized by a high total flow, for instance with forest recovery or high evapotranspiration rates in the subsequent vegetation.
The meta-analysis showed no significant differences in base flow between watersheds under natural forests and non-forest land uses (see Table 2). The effect of natural forests on base flow results from two competing processes (Calder, 2002; Bruijnzeel et al., 2004): high transpiration by the forest, contributing to a low base flow, and high infiltration under the forest, generally contributing to soil water recharge and high base flow. If the infiltration capacity of the soil is increased when converting natural forests to non-forest land uses, base flow can be increased. Natural forests conserve base flow compared to other land uses in situations where the alternative land use decreases the infiltration capacity (Bruijnzeel et al., 2004). In the meta-analysis, the base flow was higher under natural forests for the subset of large watersheds; but this result is difficult to explain. This may be due to the regional recycling of rainfall by forests (Vanclay, 2009) but this interpretation is controversial (Bruijnzeel, 2004).

Regarding storm flow, no significant difference was found between watersheds under natural forests and non-forest land uses (see Table 2). Forest hydrologists agree that the relationship between forests and storm flow is not clear (Bosch and Hewlett, 1982). Even if higher infiltration and evapotranspiration under forests may reduce storm flow, our results showed that this effect was not always significant. The role of forest cover for storm flow reduction is a debated issue, especially for the part of the storm flow that is released during extreme rainfall events (peak flow or maximum flow) and is responsible for floods. According to FAO and CIFOR (2005), there is no hard evidence that tropical forests reduce floods, while Bradshaw et al. (2007) showed that flood frequency is negatively correlated with forest cover. The effect of forests on large scale floods seems particularly weak; Bruijnzeel (2004) concluded that floods occurring in extreme conditions (e.g., extreme rainfall at the end of the rainy season when soils are wet) are not regulated by vegetation cover. Our analyses did not distinguish storm flows from rainfall events with different intensities, and thus it was not possible to determine the role of forests in regulating the peak flow resulting from extreme rainfall events. The regulation of annual storm flow is different from the regulation of peak flow resulting in large-scale floods (Bruijnzeel, 2004). However, even if forests do not prevent large scale floods, their role in preventing average and most frequent floods should not be undervalued.
2.3.3 Planted forests

In 10 of the 20 selected studies, 24 comparisons between watersheds under planted forests and non-forest land uses were analyzed. These comparisons were related mostly to watersheds smaller than 1 km² (22 comparisons), with high forest cover differences (all 24), and in humid areas (23). The selected studies referred to planted forests with species of two genera: Eucalyptus and Pinus. No studies were available for other species, including native species. This shows that there is a lack of scientific data for making decisions about planting species other than Eucalyptus and Pinus genera, as the results of the meta-analyses cannot be generalized to any planted forest in the tropics.

The meta-analyses showed that total flow and base flow were lower in watersheds under planted forests than non-forest land uses (see Table 2). These results can be explained by the high transpiration rates of exotic species, especially Eucalyptus (Vertessy et al., 2001). Infiltration capacity may be higher under planted forests than non-forest land uses (Ilstedt et al., 2007), but may not be enough to offset the higher loss of water by transpiration. However, some authors have reported that in degraded soils, planted forests may increase infiltration more than transpiration, thus increasing base flow, compared to non-forest land uses (Bruijnzeel, 2004). However, the available studies did not compare water flows between planted forests and non-forest land uses on degraded soils. Including all comparisons, the meta-analysis did not show significant differences in storm flow between watersheds with planted forests and non-forest land uses. This analysis of planted forests and storm flow was based on only five comparisons, compared to eight to 16 for other analyses.

2.3.4 Usefulness of the meta-analyses

The results of the meta-analyses allow the analysis of some misunderstandings about the effects of natural and planted forests on water flows in decision making on PES or watershed management. According to the conventional beliefs analyzed by various authors (Chomitz and Kumari, 1996; Susswein et al., 2001; Calder, 2002; Bruijnzeel et al., 2004; Kaimowitz, 2005), natural and planted forests are thought to increase total flows. This belief is deeply rooted in public perception, as was shown by Kosoy et al. (2007) in Central America, where more than 90%
of the population involved in a survey perceived that more forests would lead to higher total water flows. According to FAO (2004), many hydrological PES are based on assumptions that have not been verified in the particular case. For example, in the PES scheme in Pimampiro (Ecuador), the effect of land-use of hydrological services has not been studied (Wunder and Albán, 2008). In Costa Rica, a private hydro-energy firm pays for ecosystem services provided by forestation and forest conservation with the objective of increasing its energy production, in part through increasing total flow (Miranda et al., 2007). Three PES schemes studied by Kosoy et al. (2007) in Central America are built upon the belief that forests increase total flows.

Aylward (2005) showed that several valuations of forest hydrological services were based on the unverified assumption that natural forests would decrease storm flow and increase base flow. Among the studies valuing forest watershed services in the FAO Forest Valuation Database (FAO, 2007), three were based on unsubstantiated relationships between forests and water, for instance that forests decrease floods or increase total flows. To supply water and reduce sediment in the Panama Canal, a plan developed in the 1990s promoted planting forests among other activities, and was based on the belief that planted forests would increase total and base flows (Calder, 2002; Kaimowitz, 2005). After hurricane Mitch in Central America in October 1998, the public, decision-makers, environmentalists, and international agencies were convinced that deforestation had increased the damage, and proposed forest planting as a watershed management measure (Kaimowitz, 2005). Similarly, Bruijnzeel (2004) reported that large-scale forest planting in upper watersheds was proposed in Bangladesh and China to reduce damage caused by floods.

Even though the results of the meta-analyses should not be generalized to any tropical watershed, total flows appeared to be lower in watersheds under natural forests than non-forest land uses (for small watersheds or with high differences in forest cover). The results show no significant differences in storm flow between watersheds under natural forests and non-forest land uses. Regarding planted forests, the results showed that they reduced base flow and total flow and had no significant effect on storm flow compared to non-forest land uses. These results highlight that the effects of natural or planted forests on water flows are not the same as perceived by some decision makers. Meta-analyses can help correct misunderstandings and show
that some of the effects of natural or planted forests on water flows are unclear, and that inappropriate generalizations should be avoided (Tognetti et al., 2004).

2.3.5 Limitations

The meta-analyses faced several limitations. First, the small number of available studies limited the number of significant differences and prevented from taking into account other factors, for instance soil characteristics, geology, topography, rainfall pattern, location of land-use change in the watershed and land management in non-forest land areas, which are important factors in explaining the difference in water flows between forested and non-forested watersheds (Bruijnzeel, 2004; Aylward, 2005). Applying meta-analyses in a rigorous way is difficult with a small number of studies, especially with regards to the sensitivity analysis which is conducted on subsamples of the dataset. The following results were discarded by the sensitivity analysis: more base flow in watersheds under natural forests than under non-forest land uses (with all watersheds), less storm flow in watersheds under natural forests than under non-forest land uses (only with watersheds where forest cover differed by more than 50% of the watershed area), and less storm flow in watersheds under natural forests than under non-forest land uses (only with small watersheds).

Second, the available studies had been mostly conducted in humid areas and in some forest types (e.g., no cloud forests or planted forests with species other than of the Pinus and Eucalyptus genera). For these reasons, the results cannot be generalized to the entire tropics. Third, the available studies used different methods (e.g. for separating base flow and storm flow) and different time periods for calculating flow-rainfall ratios. A more thorough analysis of original hydrological data would be necessary to extend our simplified meta-analyses.

2.4 Conclusions

Meta-analysis appears to be a promising way to combine results from studies comparing water flows between tropical watersheds under natural or planted forests and non-forest land uses. It can help decision makers understand the effects of forests on water flows, and also highlight the effects that remain unclear. This help is necessary because even though hydrologists have published many narrative reviews about these effects, not all economists or decision makers have attempted to integrate this knowledge into the process of determining the value of
hydrological ecosystem services or for making decisions. The meta-analyses show significantly lower total flows or base flows under planted forests than non-forest land uses. Meta-analyses conducted with subsamples of the data also show lower total flow and higher base flow under natural forests than non-forest land uses. However, the available studies were restricted to humid climates and particular forest types (Pinus and Eucalyptus planted forests and lowland natural forests).

The small number of available studies with sufficient data is a major constraint in the use of meta-analysis for analyzing the effects of natural or planted forests on water flows. It impedes analyzing the interacting effect of important factors for water flow regulation, such as soil, geology, topography, or land management practices. Furthermore, the available studies with sufficient data are restricted to some local conditions or forest types and knowledge is lacking about dry areas, cloud forests, native species plantations, and plantations on degraded lands.

The lack of measurements of water flow under different land-uses and of empirical data on hydrological services represents a major technical challenge for valuation studies or payment for ecosystem services (Kremen and Ostfeld, 2005), especially in countries where financial resources for implementing field research are scarce. More empirical data on underrepresented local conditions or forest types and a facilitated access to hydrological data would be valuable for watershed managers and decision-makers. Analyzing original data about water flows, climate and watershed characteristics in a consistent way could improve further application of meta-analysis.

2.5 References


3. Decision making by farmers regarding ecosystem services: factors affecting soil conservation efforts in Costa Rica


Abstract

The impact of climate change on farm soils in the tropics is the combined result of short-term soil management decisions and expanding precipitation extremes. This is particularly true for cultivated lands located in steeply sloping areas where bare soil is exposed to extreme rainfall such as the Birris watershed in Costa Rica. Farmers in this watershed are affected by increasing degradation of soil regulation services and respond with different level of efforts to conserve their soils. This paper examines influences on farmers’ decisions through a survey involving interviews with a sample of farmers (n = 56) to test hypotheses on how a combination of cognitive variables (beliefs, risk perception, values) and socioeconomic variables shape decisions on soil conservation. Results show that farmers’ awareness of their exposure level to soil erosion combines with other variables to determine their level of soil conservation. Using discriminant analysis, three groups of farmers were identified based on their soil conservation efforts. ANOVA pairwise-comparison among these groups showed significant differences in respect to levels of awareness, perception of risk, and personal beliefs along with territorial exposure and participation in soil conservation programs. Our results help to understand farmers’ complex decision-making on soil conservation and help designing policies to support the provision of soil regulation services especially in areas highly exposed to increasing frequency of extreme precipitation events such as Central America.

Keywords: Soil regulation services, cognitive variables, Farmers decision-making, Costa Rica

3.1 Introduction

Soil erosion, land use and water management are highly interlinked. In Central America, unsustainable use of marginal lands is widespread and has caused severe soil erosion, which in turn reduces productivity of soils in upstream areas (Pimentel et al., 1995) and, downstream,
water quality regulation services (Southgate and Macke, 1989; Lutz et al., 1994a; Guo et al., 2000). In addition to these anthropogenic factors, precipitation distribution plays an important role in erosion. According to the model of Wischmeier and Smith (1978), extreme rainfall events interact with high sloping and unprotected soils, increasing kinetic potential of raindrops to remove soil particles increasing erosion and sedimentation downstream. For Central America a significant increase in intensity and frequency of extreme precipitation events has been observed (Aguilar et al., 2005) and is projected to increase further (Magrin et al., 2007).

Exposure to precipitation extremes and the high susceptibility of soils to erosion due to questionable management make this region highly vulnerable to climate change. The Costa Rican Ministry of Environment estimated that reduced soil fertility and soil erosion, partly due to the human and natural factors described above, caused a 7.7% reduction in agricultural Gross Domestic Product from 1970 to 1989 (MINAE, 2002). Moreover, the National Commission on Land Degradation (CADETI, 2002) estimates that 20% of agricultural land is severely over-utilized due to poor management practices as a result of short-term responses to productive needs of farmers.

Policies and development programs to foster soil conservation in vulnerable watersheds of tropical countries like Costa Rica use tools like direct economic incentives such as the Payment for Ecosystem Services (PES) scheme (Pagiola, 2008; Wunder et al., 2008). However, adoption rates of conservation practices in Costarican watersheds where intensive and market-oriented agricultural activities have caused large deforestation and soils are prone to intense erosion are low (Abreu, 1994). This is the case of the Birris watershed where other factors than direct payments are influencing farmers proneness to adopt soil conservation practices. Here, PES schemes need to complement existing direct incentives with other strategies to achieve intended additionality. An analysis of institutional and cognitive aspects associated with soil conservation can give insights to the design of successful programs (SWCS, 2003).

The reason for that is that often the cost-effectiveness of soil conservation programs depends on whether erosion is considered only for its off-site effects or also for on-site effects (i.e. in the latter case farmers might have a direct personal incentive to implement voluntary conservation) (Wossink and Swinton, 2007; Dale and Polanski, 2007). Soil conservation programs should, then, use complementary tools to foster adoption of adequate practices among farmers. This paper
intend to provide inputs to the design of appropriate soil conservation program while analyzing the complexity of socioeconomic and cognitive variables that influence farmers’ decision-making for soil conservation.

The objective of this paper is to analyze how cognitive and socioeconomic variables influence farmers’ decisions regarding their management of soils. More specifically, we test hypotheses, in our case study, concerning the influence of cognitive, exposure, and socioeconomic variables on farmers’ adoption of soil conservation practices. We test the following null hypotheses: i) risk perception of natural and anthropogenic activities, and knowledge of the factors causing erosion; ii) traditional socioeconomic variables (farm size, tenure, education, economic status); and iii) land characteristics, such as location in high risk areas, considered individually and together, have no effect on soil conservation decisions.

This paper is organized in the following manner. Section 2 discusses the decision-making processes of farmers related to soil conservation referring to previous literature findings. Section 3 presents the case study, and describes the model and the methods. Section 4 presents the results in terms of a series of analytical steps and the construction of cognitive variables with factor analysis. Section 5 provides discussion, followed by conclusions in Section 6.

3.2 Farmers’ Decision-Making for Soil Conservation

A large body of literature has analyzed farmers’ decision-making to inform the design of soil conservation programs. Econometric studies based on farmers’ monetary utility functions have been widely used to study adoption of soil conservation practices (Featherstone and Goodwin, 1993; Innes and Ardila, 1994; Soule et al., 2000; Illukpitiya and Gopalakrishnan, 2004; Leyva et al., 2007). Neo-classical decision models assuming maximization have been criticized by some writers as inappropriate for modeling behaviour in real world decisions since strong assumptions on cognitive aspects are required (e.g. access to perfect information, influence of social context, and individuals’ and social psychological characteristics) (Van der Bergh et al., 2000). These authors also suggest that especially in developing countries, a changed behavioural economics that includes ecological and psycho-social dimensions of agriculture is emerging.

Societal response to reduce increasing vulnerability to erosion requires physical assessments of erosion processes but also an analysis of institutional and cognitive aspects associated with the
problem and its solution (SWCS, 2003; Grothmann and Patt, 2005; Parry et al., 2007). The reason for that is that often the cost-effectiveness of soil conservation programs depends on whether erosion is perceived only for its off-site effects or also for on-site effects (i.e. in the latter case farmers might have a direct incentive to implement voluntary conservation) (Wossink and Swinton, 2007). Indeed, actions directed to improve soil regulation have the potential to benefit other societal sectors. For example, soil management practices such as using low soil-removal ploughs can reduce soil erosion but also increase water infiltration (Swinton et al., 2007; Dale and Polanski, 2007).

When studying farmers’ conservation behaviour, the perception of uncertain costs and benefits of conservation practices is also relevant. As prospect theory (Tversky and Kahneman, 1974) and other theories indicate, decision-making under uncertainty is influenced by cognitive aspects such as what is considered a loss or gain, experience, individual values and a series of beliefs about the functioning of the system in which decisions are made.

To study farmers’ voluntary conservation efforts, Gould and colleagues (1989) used a three phase decision model: identifying the problem, deciding on adoption and determining the level of effort. These authors found that, for socioeconomic variables, the effect of farm size on adoption of soil conservation practices was negative while that of income was positive. In the case of cognitive variables, the perception of severity of impacts of soil erosion was positive. Similarly, Lynne et al. (1988) combined psychological variables measuring attitudes, with economic variables, such as income and tenure. In their model, attitudes were used as an expression of expected value attached to a given conservation activity. These authors found that cognitive and psychological variables such as beliefs on conservation of and responsibility on management of soil had a positive effect on adoption of soil conservation practices.

Along the same line, the on-site perceived effects of conservation behaviour were analyzed by Traore et al. (1998), who confirmed that perception of environmental problems by farmers was corresponded by a higher adoption degree of environmental-friendly agricultural practices, while socioeconomic variables like tenure and farm size were not significant.

The role of risk perception, beliefs, values and socioeconomic variables in farmers’ decision-making on soil conservation has been a concern of environmental policies to address climate change threats. Risk perception, environmental values (cost-benefit expectancy) and beliefs (i.e.
knowledge base) have different explanatory power for decisions that address environmental change (O’Connor et al., 1999; Siegrist and Gutscher, 2006). For example, Lee and Zhang (2005) used psychometric measurements to analyze farmers’ attitudes and risk perceptions of land degradation along with socioeconomic variables. These authors measured the risk perceptions of farmers for the effects of grazing, opening up farmland, cutting trees for fuel-wood and digging up a local traditional plant on land degradation. Type of occupation and age have a positive effect on awareness of land degradation and on the perception of its impacts. Farmers perceive the existence of different ecological risks associated with land degradation activities although significant misconceptions on land degradation causes and impacts exist among farmers’ and experts’ knowledge.

Another approach, utilized by Bayard and Jolly (2007), adapted the Health Belief Model as a modified version of Ajzen’s theory of Planned Behaviour (1991). In their approach, psycho-social, physical and economic constructs were used to measure persons’ beliefs about costs and benefits of a given behaviour which determine intention and soil conservation behaviour. More specifically, four components associated with the risk of soil degradation were included: perceived susceptibility (e.g. exposure); perceived severity (e.g. size of impacts); perceived benefits (private vs public), and barriers (e.g. perceived behavioural control). The findings confirm that awareness of the problem has a positive effect on soil conservation behaviour, while attitudes had no significant effect. On the other side, awareness is positively influenced by farmers’ higher perception of severity and susceptibility of soil degradation risk.

Explicitly accounting for climate change risk, Grothmann and Patt (2005) used the Private Proactive Adaptation to Climate Change decision model. In this model, farmers’ access to resources, institutional barriers, experience, the perception of probability and severity of climate-related events and, finally, perceived capacity to respond were determinants in farmers’ adoption of responsive behaviour. These authors applied qualitatively their model to the case of farmers’ adoption of climate forecast information in their farming decisions. They could show that there is inconsistency among farmers’ and experts’ assessment of risk and that low perceived self-adaptive capacity hinder adoption of risk-preventive behaviour. In Central America, farmers’ soil conservation decisions have been studied mainly from a traditional
utilitarian perspective, with some exceptions found in the recompilation of Central America case studies on economic and institutional analysis of soil conservation projects (Lutz et al., 1994). None of these regional studies analyzed the influence of risk perceptions and beliefs concerning anthropogenic activities and natural events as determinants of preventive behaviour of soil erosion control. Considering the concerns of the international community and national policies on reducing the potential impacts of climate change, it is relevant to explore how and whether risk and causes of soil erosion are perceived and whether these influence farmers’ conservation efforts in a highly vulnerable region.

3.3 Methods

3.3.1 Description of the area

The Birris (coordinates 9.9° N, 83.8° W) is a sub-watershed of the Reventazon River in central Costa Rica flowing into the Caribbean, and is 4800 hectares in size. The watershed is influenced by the Caribbean climate, with 2325 mm average annual rainfall of which about 80% is concentrated in the period from May to December. The topography is characterized by slopes of up to 70 %, especially in the upper part of the watershed. The population density is 161 inhabitants per square kilometer (i.e. above the national average; INEC, 2002); most inhabitants are locally born and the majority (61%) are involved in agriculture (ICE, 2000).

Large-scale land conversion of the cloud forest in the Birris watershed started in the 1960s when horticulture and dairy-cattle pastures were established. Intensive soil use for horticulture (217 producers of potato, cabbage and carrots with 2.5 ha average farm size) and dairy-cattle pastures (122 producers with 5 to 7 ha average farm size), is found mainly in riparian areas. Agriculture and infrastructures have reduced the cover of tropical cloud forest to 28% of the total land area in the watershed. This intense process of forest fragmentation and intensive agricultural production makes this area one of the largest sediment-producers in the country (Sanchez-Azofeifa et al., 2002). Average erosion rates grew from 12 ton/ha/yr prior to 1978, when only 15% of the watershed was under horticulture, to 42 ton/ha/yr in 1992 (Abreu, 1994). However, the effect of these high levels of erosion is only visible in some areas\(^3\), since deep andosols are

\(^3\)That is, probably only some farmers are starting to perceive its direct impacts of erosion.
common in the area (Lutz et al., 1994b; Marchamalo and Romero, 2007). To date the National Electricity Institute (ICE) yearly spends more than four million US$ to clean its dams and around three hundred thousand US$ to promote the soil watershed management plan. On the other side the ministry of agriculture provides human and logistic resources to promote soil conservation practices in upstream areas. Here, a recent estimation of the reposition cost of soil nutrients lost with erosion corresponds to ninety-five thousands US$ a year (Vignola et al., 2010).

3.3.2 Sample and Survey Instrument Design
To develop the survey instrument we conducted two focus groups and interviews with key informants (farmers and agricultural extension officers) to identify aspects to be included in the analysis of farmers’ adoption of soil conservation practices in the Birris watershed. Additionally, we also reviewed instruments applied in previous farmers’ adoption studies that analyzed attitudes and values related to soil conservation (see section 3.3). We reviewed questions with agricultural extension officers to ensure that they would be easily understood by farmers. A pilot test was conducted with five farmers to further clarify questions.

Our sample \((n = 56; N = 300)\) is covering around 18% of all farmers in the watershed and is similar to that of previous studies similar studies \((n = 64; \text{Bewket}, 2007)\). Three lists of producers available from the local agriculture extension office were used for a strata-proportional selection of farmers corresponding to three categories of producers present in the watershed: horticulture and dairy-cattle \((n = 10)\), horticulture only \((n = 35)\) and dairy-cattle only \((n = 11)\). Producers were visited in the field or at home and were administered by pre-trained interviewers a half-hour structured interview consisting of the following sections: i) soil conservation practices implemented; ii) perception of farm soil quality; iii) risk factors contributing to soil erosion; iv) values that influence soil conservation decisions; and, finally v) questions regarding socio-economic data.

3.3.3 The Decision Model
Building on Bayard and Jolly (2007), we propose the following model of farmers’ decisions to adopt soil conservation:

\[
CD = f (B, RP, V, SE),
\]
where soil conservation decisions \((CD)\) depend on three types of independent variables such as their belief/knowledge \((B)\), their risk perceptions \((RP)\), values \((V)\) and a set of socio-economic characteristics \((SE)\). This model served as the basis of the research design discussed below.

To measure farmers’ soil conservation behaviour we used secondary literature and key informants (e.g. agricultural extension officers and members of farmers associations) to build a list of conservation practices that are promoted by existing extension programs or by farmers themselves in the watershed (ICE, 2000; Marchamalo, 2004). The list of conservation practices includes planting of trees, cultivation along contour lines, use of water and soil conservation channels, natural regeneration of vegetation in critical areas, among others. We constructed a binary vector for each practice by asking respondents to mark those practices on the list that they were implementing when the interviews were conducted.

We then constructed for each farmer \(i\) the dependent categorical variable soil conservation effort \(CE(i)=1\) for low effort, \(CE(i)=2\) for medium effort, and \(CE(i)=3\) for high effort. To do this, we first have to consider that there are different numbers of possible protection practices \(P_j(i)\) for each productive category \(j\) (\(j = 1\) for cattle breeding; \(j = 2\) for horticulture, \(j = 3\) for both practices). For a farmer \(i\) belonging to production category \(j\), we calculate the conservation score:

\[
Y_{\text{Cons}}^j(i) = \frac{P(i)}{T_j},
\]

where \(P(i)\) is the total number of practices implemented by the farmer \(i\) and \(T_j\) is the total number of possible practices for productive category \(j\). The conservation score variable was used to define \(CE(i)\) by: \(CE(1)\) if less than half of the protection practices are applied (i.e. if \(Y_{\text{Cons}}^j(i) < 0.5\)); \(CE(2)\) if more than half and up to 75% of the production practices are applied (i.e. if \(0.5 \leq Y_{\text{Cons}}^j(i) \leq 0.75\)); and \(CE(3)\) if more than three-quarters of all possible practices are applied (i.e. if \(0.75 < Y_{\text{Cons}}^j(i)\)).

**Cognitive variables**
We draw on similar studies (Bewket, 2007) that used explanatory variables of farmers’ decisions to implement soil conservation, such as awareness and perception of erosion hazard, its causes and controllability. In this section, we explore key concepts underlying these cognitive variables. Farmers’ beliefs ($B$) guide their understanding and evaluation of causes and solutions associated with erosion control (D’emden et al., 2008). We followed the approach of Wagner (2007), who used mental model questions to elicit lay-people’s beliefs on causes of flash floods, and Bewket (2007) who asked farmers about their beliefs on causes of soil erosion. Rankings on the importance of five degradation activities reported by recent studies (ICE, 2000; Marchamalo, 2004; Ramirez, 2008) were used, namely: deforestation, agricultural practices, extreme precipitation, urbanization, and dairy cattle pastures. We also asked questions on whether they perceive that the “general health”$^4$ of their soil has changed from the past and whether they think it will change in the future as a way to measure their judgment on the continuity of the erosion problem over time. Additionally, perceptions on the positive role of trees in erosion control and riparian protection, as recognized in the literature (Tejwani 1993; Bruijnzeel, 2004) and promoted by soil conservation programs, were measured.

Risk perception ($RP$) was measured following the psychometric paradigm which allows identification of differences in perceptions among groups of individuals (Slovic, 1987). In this paper, risk perception merely denotes the cognitive representation and evaluation of negative impacts resulting from a given activity that changes the environment. Risk of erosion can be defined as consequence-related risk that, using the classification of Slovic (1987), can be judged observable, is relatively well-known to scientists, has immediate effect and, considering the highly exposed context of our study, is a relatively well-known and old problem in the area. In this study, the identification of risk constructs was adapted from previous studies that analyzed the relationship among environmental risk sources and behavioural intentions and responses (McDaniels et al., 1996; McDaniels et al., 1997; O’Connor et al., 1999; Lee and Zhang, 2005; Bayard and Jolly, 2007).

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$^4$ This concept was used by key informants when discussing on soil erosion. Soil erosion is associated by farmers to the concept of decreasing soil health which they perceive associated to several consequences such as decreasing productive capacity and increase in amount of fertilizers needed.
Farmers’ decisions regarding soil conservation are largely driven by short-term perceived risks associated with markets and weather, rather than long-term climate change-related hazards (Grothmann and Patt, 2005). To model this component, and following Bayard and Jolly (2007), we built constructs to measure risk perception using Likert scales from one to seven to measure the individuals’ perception of the immediacy and saliency of impacts from drivers of soil erosion such as agriculture, cattle, rainfall, and logging and urbanization. This immediacy was measured by four constructs; namely, severity, uncontrollability, observability and rapidity. Additional questions were intended to measure the extent to which individuals perceive themselves to be living in areas generally exposed to soil erosion risk.

Values \( V \) characterize those standards that individuals judge appropriate and desirable in a given situation, and thus reflect their ordering of preferences for end-states of the environment (Scholz, n.d.). We build, for the value items, on Lee and Zhang (2005) and O’Connor et al. (1999) to formulate questions on how much farmers and public administration should be held responsible for avoiding damage to soil. Finally, all items used to measure all our cognitive variables are presented in table 1.
Table 1: Items and their codes to measure cognitive variables.

<table>
<thead>
<tr>
<th>Component</th>
<th>Abbreviations</th>
<th>Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belief</td>
<td>BProdInRipAgua</td>
<td>Riparian areas are optimal for my productive activities given proximity to water.</td>
</tr>
<tr>
<td></td>
<td>BProdRipGood</td>
<td>Sloping areas are good for my productive activity.</td>
</tr>
<tr>
<td></td>
<td>BSoilConsCostInco</td>
<td>Soil conservation measures don’t bring much benefit, it is more the investment cost then the returns for my farm.</td>
</tr>
<tr>
<td></td>
<td>BSoilNeverDegr</td>
<td>Soil is an inexhaustible resource, which is why it can be exploited continuously.</td>
</tr>
<tr>
<td></td>
<td>BScienceTech</td>
<td>Scientific and technological progress in soil management allows overcoming soil degradation problems.</td>
</tr>
<tr>
<td></td>
<td>BSoilHealth*</td>
<td>How healthy do you think your soil is?</td>
</tr>
<tr>
<td></td>
<td>BSHchange**</td>
<td>Do you consider that your soil health has changed compared to the past?</td>
</tr>
<tr>
<td></td>
<td>BSHChFut</td>
<td>Do you think your soil health might change in the future?</td>
</tr>
<tr>
<td></td>
<td>BContrPreci</td>
<td>How much does rainfall contribute to erosion?</td>
</tr>
<tr>
<td></td>
<td>BContrAgr</td>
<td>How much do agricultural practices contribute to soil erosion?</td>
</tr>
<tr>
<td></td>
<td>BImpoRain</td>
<td>Among deforestation, agriculture, rainfall, roads and cattle breeding, how would you rank precipitation impacts on soil erosion?</td>
</tr>
<tr>
<td></td>
<td>BImpoAgr</td>
<td>Among deforestation, agriculture, rainfall, roads and cattle breeding, how would you rank the impacts of agricultural activities on soil erosion?</td>
</tr>
<tr>
<td>Risk</td>
<td>BTreesDecrProd</td>
<td>Trees on farm lands decrease production.</td>
</tr>
<tr>
<td></td>
<td>BTreeConsSoil</td>
<td>Trees benefit soil conservation.</td>
</tr>
<tr>
<td></td>
<td>BSlopeFor</td>
<td>In high sloping areas there should be no productive activity, only forest.</td>
</tr>
<tr>
<td></td>
<td>RPCattleObs</td>
<td>How observable is the impact of cattle on soil erosion?</td>
</tr>
<tr>
<td></td>
<td>RPCattleRap</td>
<td>How fast is the impact of cattle on soil erosion?</td>
</tr>
<tr>
<td></td>
<td>RPAgrRap</td>
<td>How fast is the impact of agriculture on soil erosion?</td>
</tr>
<tr>
<td></td>
<td>RPCattleSev</td>
<td>How large is the impact of cattle on soil erosion?</td>
</tr>
<tr>
<td></td>
<td>RPAgrObs</td>
<td>How observable is the impact of agriculture on soil erosion?</td>
</tr>
<tr>
<td></td>
<td>RPAgrSev</td>
<td>How large is the impact of agricultural activities on soil erosion?</td>
</tr>
<tr>
<td></td>
<td>RPEroPast</td>
<td>How much has erosion risk increased in respect to the past?</td>
</tr>
<tr>
<td></td>
<td>RPEroFut</td>
<td>How much will soil erosion risk increase in the future?</td>
</tr>
<tr>
<td></td>
<td>RPCrSev</td>
<td>How large are soil erosion related losses in Costa Rica?</td>
</tr>
<tr>
<td></td>
<td>RPCrContr</td>
<td>How much can people in Costa Rica control the risk of soil erosion?</td>
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<tr>
<td></td>
<td>RPRainObs</td>
<td>How observable is the impact of precipitation on soil erosion?</td>
</tr>
<tr>
<td></td>
<td>RPRainSev</td>
<td>How large is the impact of precipitation on soil erosion?</td>
</tr>
<tr>
<td></td>
<td>RPRainRap</td>
<td>How fast is the impact of precipitation on soil erosion?</td>
</tr>
<tr>
<td></td>
<td>RPCRContr</td>
<td>How controllable is the impact of precipitation on soil erosion?</td>
</tr>
<tr>
<td></td>
<td>RPCrContr</td>
<td>How controllable is the impact of cattle on soil erosion?</td>
</tr>
<tr>
<td></td>
<td>RPRainContr</td>
<td>How controllable is the impact of precipitation on soil erosion?</td>
</tr>
<tr>
<td></td>
<td>RPAgrContr</td>
<td>How controllable is the impact of agriculture on soil erosion?</td>
</tr>
<tr>
<td>Values</td>
<td>VSoilProdNoDestr</td>
<td>Soil productivity should never be destroyed</td>
</tr>
<tr>
<td></td>
<td>VwstrUseCare</td>
<td>Downstream users don’t care about how we upstream producers manage our farm soils</td>
</tr>
<tr>
<td></td>
<td>VincomeNow</td>
<td>Ensuring maximum return possible for this year is much more important than ensuring soil productivity for future generations</td>
</tr>
<tr>
<td></td>
<td>VProdPay</td>
<td>Producers who are responsible for sedimentation in rivers should pay for removing such sediments from rivers and dams</td>
</tr>
<tr>
<td></td>
<td>VProdOwnDec</td>
<td>Each producer owns his farm soil so that his soil management decisions are strictly personal</td>
</tr>
<tr>
<td></td>
<td>VRespFutGenr</td>
<td>For our children, we producers have the responsibility to reduce erosion</td>
</tr>
<tr>
<td></td>
<td>VPublicAdmPay</td>
<td>Public administration responsible for roads should pay for removing sediments produced by this infrastructure from rivers and dams</td>
</tr>
</tbody>
</table>

All variables are measured on Likert-scales. Beliefs scales are 1 (do not agree) to 7 (very much agree); except * (very unhealthy =1 to very healthy =4) and ** (Has worsened = 1, the same as now = 2, has improved = 3); Risk perceptions are from 1 (very little) to 7 (very large); Values scales are 1 (do not agree) to 7 (very much agree).

Socioeconomic variables

As reported in other studies (Grasmuck and Scholz, 2005; Siegrist and Gutscher, 2006) risk perception and its associated responsive behaviour is influenced by individuals’ exposure. We
created a binary variable to discriminate producers by risk areas that were identified by polygons (see Figure 1) reflecting the boundaries of communities subject to the highest rates of soil erosion (Marchamalo, 2004).

Figure 1: Location, current land uses and the delimitation of areas with high soil erosion of the Birris watershed, (A: Costa Rica; B: Reventazon watershed; C: Birris watershed).

Existing programs promoting soil conservation in the Birris watershed cover a limited extent of the area. To account for their eventual influence on individuals’ judgment and conservation behaviour, participation in an existing program was measured with a binary variable. Economic welfare level was included, similar to other studies (Lynne et al., 1988; O’Connor et al., 1999; Lee and Zhang, 2005; Bayard and Jolly, 2007), with a ranking variable of monthly household consumption with seven levels. As seen in section 2, land tenure has widely been used in studying farmers’ adoption of soil conservation practices. So, based on our recollected data we constructed an ownership variable (“owned”) which measures the percentage of total farm land
that is owned by the individual producer. Finally, education level (measured by 5 levels) and age of individuals were included for their important role outlined in previous research on farmers’ conservation behaviour (Traore et al., 1998; Illukpitiya and Gopalakrishnan, 2004; Lee and Zhang, 2005).

3.3.4 Statistical analysis

3.3.4.1 Construction of cognitive variables

In what follows we describe how we used factor analysis in SPSS (2001) on $B$, $RP$, and $V$ to create three indexes that were ultimately used, together with socioeconomic variables, to test our hypotheses. The three sets of indexes $(B, RP, V)$ were obtained by conducting the factor analysis with the Kaiser normalization method, varimax rotation, and Principal Component Analysis as the extracting method with the variables under each heading in table 1. Only factors with an eigenvalue of 1 or above were retained (Kaiser-Gutmann retention criterion; Kinnel et al., 2002). Fitness for factorial analysis was tested with Bartletts’ KMO and $p$-value. Rotated factor loadings were used to identify relevant variables to be used in the construction of indexes. Variables were retained if their rotated loadings were above the threshold value of 0.5.

In the exploratory analysis, we excluded from further analysis the variable that measured farmers’ judgment on “own responsibility not to destroy soil productivity” $(V_{\text{SoilProdNoDestr}})$ for its low variance (ratings between 5 and 7), possibly due to strategic answering. Then, a separate factor analysis (i.e. one for each specific cognitive aspect of the decision model) reduced the number of variables from the original 38 to 9 cognitive indexes. In each factor analysis we utilized standard procedures such as $KMO$ values and commonalities to improve the separation of factors. The final results are shown in table 2.

Table 2: Socio-economic variables of the sample (n = 56).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Average</th>
<th>S.D.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>48.98</td>
<td>14.55</td>
<td>18</td>
<td>80</td>
</tr>
<tr>
<td>Farm size</td>
<td>18.30</td>
<td>11.11</td>
<td>1</td>
<td>38</td>
</tr>
<tr>
<td>Education level</td>
<td>2.29</td>
<td>0.87</td>
<td>1</td>
<td>5</td>
</tr>
</tbody>
</table>

In an attempt to reduce the number of variables, we ran exploratory factor analyses using all variables measuring cognitive aspects. The low fitness-test value ($KMO = 0.352; p < 0.0001$), however, did not separate consistent factors out of the 14 loaded, thus suggesting the need for a minor-aggregation analysis.
Beliefs. The factor analysis on beliefs variables identified 3 underlying factors (KMO = 0.671; p < 0.01). With factor 1 loadings, we constructed an index $B_1$ called “Positive Thinking” ($B_1 = B_{ProdInRipagua} + B_{SoilNeverDegr} + B_{ScienceTech}$) composed of items capturing i) beliefs that soils are resilient to degradation, ii) that technological progress in soil management practices is sufficient to counter soil degradation and, finally, iii) that producing in riparian areas (i.e. sloping areas) is good because water is closer. This index thus indicates the triumph of positive thinking about production and technology over worries on soil degradation processes. Items from factor 2 loadings built index $B_2$ named “soil critical conditions” ($B_2 = B_{SoilHealth} + B_{RSHchange}$). These items measure beliefs as to how healthy farmers think their farm soil is and whether it has changed. The scales of the two contributory items were structured to measure how strongly they believe their farm soil to be in critical condition (i.e. higher values correspond to higher awareness of critical soil conditions). Factor 3 loadings identified beliefs associated with the importance of rainfall in erosion processes in general and in their farm soil in particular. Index $B_3$, termed “Climate extremes” ($B_3 = B_{ContrPreci} + B_{ImpoRain}$), captures beliefs associated with this component of the erosion problem.

Risk perception. Factor analysis for risk perception (KMO = 0.71; p < 0.0001) identified four factors. Factor 1 loadings identified an underlying index $RP_1$ called “Agricultural risk” ($RP_1 = RP_{AgrContr} + RP_{AgrObs} + RP_{AgrSev} + RP_{AgrRap}$), which captures risk perception associated with agricultural activities. More specifically, it measures the immediacy of their impacts on erosion and how controllable they are and tells us about the relevance of these activities for erosion. Based on the loadings of the second factor, we constructed index $RP_2$, termed “Pasture risk”, ($RP_2 = RP_{CattleObs} + RP_{CattleSev} + RP_{CattleRap}$), representing the perception associated with the immediacy and severity of pasture activities on erosion. The index $RP_3$ ($RP_3 = RP_{EroPav} + RP_{RainObs} + RP_{RainRap}$) is named “Extreme Precipitation” and clearly complements the first two risk perception indexes, which are directed at anthropogenic activities, by
addressing judgment on natural phenomena. This index includes perception of the immediacy of rainfall impacts which, interestingly, is correlated in the same factor with the perception of how strongly erosion has increased in respect to the past. Finally, in the factor analysis of risk perception, the fourth factor loaded items measuring perception of the controllability of erosion effects together with the extent to which individuals perceive that people in the country are able to control this environmental problem. We name index \( R_{P_4} \) “control perception” \( (R_{P_4} = R_{P_{CrContr}} + R_{P_{RainContr}}) \) since it measures perceptions of how controllable the erosion effects of extreme precipitation are, along with the capacity of Costa Rican people to cope with them.

Values. Factor analysis on values items identified two underlying factors \((KMO = 0.559; p < 0.05)\). The first factor loaded items measuring values on private aspects of the erosion problem. Thus, this index called “private benefits” \( (V_1 = V_{IncomeNow} + V_{ProdOwnDec} + V_{ProdNoPay}) \) measures preference for short-term benefits, right to decision on their own farm soil (i.e. erosion is not of public concern) and, finally, the opinion that producers should not be paying for removing sediments from the river. The second factor, in contrast, identified an index \( (V_2 = V_{RespFutGenr} + V_{PublicAdminPay}) \) that captures the values related more to the public than to the private benefits. This index is built with variables measuring concerns on whether public administration (i.e. and not individual farmers) should be held responsible for removing sediment from rivers and whether soil conservation should be ensured for the benefits of future generations (i.e. expressing concerns for longer-term benefits of erosion control).

3.3.4.2 Differentiation of farmers’ types

In a second step, following Carlsson et al. (1977), we used discriminant analysis, using \( CE(i) \) as the dependent variables, to project the socioeconomic and cognitive indexes in a bi-dimensional space allowing for visual representation of the farmers’ conservation-efforts groups and the variables characterizing them. Finally, we tested our hypotheses in section 1 with a pair-wise ANOVA to compare groups’ means scores on cognitive and socioeconomic variables.
3.4 Results

3.4.1 Sample description

Most farmers in our sample are full-time agricultural producers (63%) and have relatively low educational levels (i.e. primary school). The average level of household monthly consumption is between US$ 200 and US$ 400 (Table 3).
Table 3: Results of factor analysis with the loadings of the rotated factors for cognitive variables.

<table>
<thead>
<tr>
<th>Dimension</th>
<th>variable</th>
<th>Factor 1</th>
<th>Factor 2</th>
<th>Factor 3</th>
<th>Factor 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Explained variance</td>
<td>31.32</td>
<td>15.74</td>
<td>14.85</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Rotated loadings</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beliefs</td>
<td>BProlInRipAgua</td>
<td>0.82</td>
<td>0.13</td>
<td>0.09</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>BScienceTech</td>
<td>0.70</td>
<td>-0.05</td>
<td>0.26</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>BSoilNeverDegr</td>
<td>0.67</td>
<td>0.22</td>
<td>-0.16</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>BSoilHealth</td>
<td>-0.04</td>
<td>0.83</td>
<td>0.19</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>BSHchange</td>
<td>0.37</td>
<td>0.7</td>
<td>-0.07</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>BContrPreci</td>
<td>0.32</td>
<td>-0.001</td>
<td>0.67</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>BImpoRain</td>
<td>0.11</td>
<td>-0.11</td>
<td>-0.74</td>
<td>-</td>
</tr>
<tr>
<td>Risk perception</td>
<td>Explained variance</td>
<td>33.18</td>
<td>14.643</td>
<td>10.801</td>
<td>10.459</td>
</tr>
<tr>
<td></td>
<td>Rotated loadings</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>RP AgrContr</td>
<td>0.65</td>
<td>0.19</td>
<td>-0.12</td>
<td>0.42</td>
</tr>
<tr>
<td></td>
<td>RP AgrObs</td>
<td>0.85</td>
<td>0.03</td>
<td>0.11</td>
<td>-0.09</td>
</tr>
<tr>
<td></td>
<td>RP AgrSev</td>
<td>0.76</td>
<td>0.22</td>
<td>0.12</td>
<td>-0.10</td>
</tr>
<tr>
<td></td>
<td>RP AgrRap</td>
<td>0.72</td>
<td>0.29</td>
<td>0.39</td>
<td>-0.15</td>
</tr>
<tr>
<td></td>
<td>RPCattleContr</td>
<td>0.59</td>
<td>0.31</td>
<td>0.06</td>
<td>0.43</td>
</tr>
<tr>
<td></td>
<td>RPCattleObs</td>
<td>0.27</td>
<td>0.81</td>
<td>0.09</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td>RPCattleSev</td>
<td>0.21</td>
<td>0.92</td>
<td>0.04</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>RPCattleRap</td>
<td>0.12</td>
<td>0.92</td>
<td>0.04</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>RPRainObs</td>
<td>0.07</td>
<td>0.03</td>
<td>0.72</td>
<td>-0.28</td>
</tr>
<tr>
<td></td>
<td>RPRainRap</td>
<td>0.09</td>
<td>0.15</td>
<td>0.63</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>RPEroPast</td>
<td>-0.11</td>
<td>0.06</td>
<td>-0.70</td>
<td>-0.15</td>
</tr>
<tr>
<td></td>
<td>RPCrContr</td>
<td>0.02</td>
<td>0.04</td>
<td>-0.19</td>
<td>0.74</td>
</tr>
<tr>
<td></td>
<td>RPRainContr</td>
<td>-0.12</td>
<td>0.11</td>
<td>0.32</td>
<td>0.75</td>
</tr>
<tr>
<td>Values</td>
<td>Explained variance</td>
<td>33.82</td>
<td>23.39</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Rotated loadings</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>VincomeNow</td>
<td>0.71</td>
<td>0.41</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>VProdNoPay</td>
<td>0.75</td>
<td>0.25</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>VProdOwnDec</td>
<td>0.73</td>
<td>0.07</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>VRespFutGenr</td>
<td>0.03</td>
<td>0.71</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>VPublicAdmPay</td>
<td>0.005</td>
<td>0.70</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

The majority of interviewees (71%) do not, at present, participate in conservation programs and the sample shows a relatively even distribution of farmers in and outside (46%) of risk areas.
Farmers in the sample, independently from their farm production activity, implement on average about half (55%) of the total soil conservation practices we listed.

3.4.3 Differentiation of farmers’ groups

Combined cognitive and socioeconomic variables clearly differentiate the three groups of farmers based on their conservation efforts (CE). Agriculturalists represent the majority of interviewees in the groups CE(1) and CE(2) (i.e. lower conservation efforts) (Table 4).

<table>
<thead>
<tr>
<th>Farm activity</th>
<th>Farmers’ groups (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CE(1)</td>
</tr>
<tr>
<td>Agriculture</td>
<td>13</td>
</tr>
<tr>
<td>Dairy-cattle</td>
<td>3</td>
</tr>
<tr>
<td>Agriculture and dairy</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>19</td>
</tr>
</tbody>
</table>

Table 4: Distribution of interviewees by farm activity in the different farmers’ conservation-effort groups of the sample.

Farmers within the group of lowest conservation efforts CE(1) own a smaller percentage of the land they cultivate respect to farmers in the other two groups. The bi-plot of discriminant analysis (Figure 2) identifies three separate groups of farmers distinguished using circles built with the confidence interval at $p$-value lower than 0.05. The first canonical axis explains more than 70% of total variance and allows a clear separation between the group of farmers with greater conservation efforts CE(3) from that of group CE(1). Clearly, group CE(3) is strongly and positively associated with exposure in risk areas, higher education level, more participation in programs and more “public benefits” ($V_2$) concerns. The figure also shows that in this group, given the negative association with socioeconomic variables such as “age” and “own”, we find younger farmers owning a smaller portion of land with respect to total land farmed. Similarly, group CE(3), in contrast to CE(1), is also strongly negatively associated with risk perceptions of “Agricultural risk” and of “extreme precipitation”. The differences between these two groups are also reflected in their contrasting association with beliefs on topics such as “soil critical conditions” and “climate extremes”.

---

6 Data are consistent for linear discriminant analysis since the null hypotheses for the homogeneity of variance is accepted ($p = 0.4646$).
Indexes such as “positive thinking” ($B_1$) beliefs and “pasture risk” ($RP_1$) perceptions are only slightly important with respect to the first canonical axis. In the second canonical axis, it is only cognitive index $B1$ which shows a strong and positive association with $CE(2)$. Similarly, it is only with respect to this axis that the index “private benefits” ($V_1$) shows a stronger contribution, being positively associated with $CE(1)$ and negatively with group $CE(2)$.

![Figure 2: Discriminant analysis for the three groups of farmers with different soil conservation efforts $CE(i)$. Blue triangles correspond to $CE(1)$, yellow squares to $CE(2)$ and green circles to $CE(3)$. The grey lozenge represents the spatial location of the variable, showing its positive or negative association with farmers groups.](image)

3.4.4 Testing hypotheses of differences between farmers’ groups

The clear separation among groups of farmers (defined by their conservation effort) resulting from the discriminant analysis rejects our null hypothesis supporting that a combination of socioeconomic and cognitive variables explain significant differences among farmers’
conservation efforts. In the following pairwise ANOVA we refine our hypotheses testing to highlight the differential contribution of cognitive and socioeconomic variables by groups of farmers. Results of ANOVA show key contrasting characteristics of the three groups of farmers (table 5).

Table 5: Pair-wise ANOVA comparison of the three farmers’ groups; CE(i) identifies the Conservation-Effort farmers’ group.

<table>
<thead>
<tr>
<th>Variables</th>
<th>CE(1) (mean, SD)</th>
<th>CE(2) (mean, SD)</th>
<th>CE(3) (mean, SD)</th>
<th>CE(1) vs CE(2) p-value</th>
<th>CE(1) vs CE(3) p-value</th>
<th>CE(2) vs CE(3) p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PartiProgr</td>
<td>0.11 (0.31)</td>
<td>0.14 (0.35)</td>
<td>0.69 (0.47)</td>
<td>0.48</td>
<td>0.0005</td>
<td>0.001</td>
</tr>
<tr>
<td>Activity</td>
<td>2.24 (0.53)</td>
<td>2.24 (0.53)</td>
<td>1.75 (0.68)</td>
<td>0.23</td>
<td>0.29</td>
<td>0.03</td>
</tr>
<tr>
<td>Age</td>
<td>48.53 (14.79)</td>
<td>52.57 (16.08)</td>
<td>44.81 (11.50)</td>
<td>0.39</td>
<td>0.39</td>
<td>0.13</td>
</tr>
<tr>
<td>Edu</td>
<td>2.37 (0.83)</td>
<td>2.08 (0.83)</td>
<td>2.56 (0.89)</td>
<td>0.21</td>
<td>0.44</td>
<td>0.08</td>
</tr>
<tr>
<td>MonthCons</td>
<td>4.21 (1.18)</td>
<td>4.33 (1.71)</td>
<td>4.88 (1.02)</td>
<td>0.49</td>
<td>0.11</td>
<td>0.28</td>
</tr>
<tr>
<td>Owned</td>
<td>0.70 (0.43)</td>
<td>0.83 (0.33)</td>
<td>0.70 (0.40)</td>
<td>0.33</td>
<td>0.50</td>
<td>0.34</td>
</tr>
<tr>
<td>RiskArea</td>
<td>0.21 (0.41)</td>
<td>0.48 (0.51)</td>
<td>1.00 (0)</td>
<td>0.10</td>
<td>0.0001</td>
<td>0.0002</td>
</tr>
<tr>
<td>B1</td>
<td>11.89 (4.93)</td>
<td>14.47 (4.45)</td>
<td>10.50 (4.80)</td>
<td>0.12</td>
<td>0.39</td>
<td>0.02</td>
</tr>
<tr>
<td>B2</td>
<td>4.42 (1.017)</td>
<td>4.09 (0.94)</td>
<td>3.87 (1.08)</td>
<td>0.22</td>
<td>0.17</td>
<td>0.48</td>
</tr>
<tr>
<td>B3</td>
<td>9.78 (1.81)</td>
<td>10.04 (2.17)</td>
<td>8.81 (2.28)</td>
<td>0.48</td>
<td>0.22</td>
<td>0.14</td>
</tr>
<tr>
<td>RP1</td>
<td>19.84 (3.46)</td>
<td>15.90 (4.08)</td>
<td>15.93 (3.51)</td>
<td>0.003</td>
<td>0.003</td>
<td>0.50</td>
</tr>
<tr>
<td>RP2</td>
<td>9.63 (6.83)</td>
<td>6.42 (4.17)</td>
<td>9.43 (4.76)</td>
<td>0.12</td>
<td>0.49</td>
<td>0.07</td>
</tr>
<tr>
<td>RP3</td>
<td>17.63 (2.31)</td>
<td>16.52 (2.69)</td>
<td>17.56 (2.09)</td>
<td>0.21</td>
<td>0.49</td>
<td>0.24</td>
</tr>
<tr>
<td>RP4</td>
<td>6.47 (3.19)</td>
<td>6.81 (3.22)</td>
<td>5.56 (2.06)</td>
<td>0.49</td>
<td>0.34</td>
<td>0.21</td>
</tr>
<tr>
<td>V1</td>
<td>13.42 (3.99)</td>
<td>8.38 (3.74)</td>
<td>10.25 (4.41)</td>
<td>0.0003</td>
<td>0.05</td>
<td>0.22</td>
</tr>
<tr>
<td>V2</td>
<td>10.78 (3.13)</td>
<td>10.80 (2.37)</td>
<td>12.56 (1.36)</td>
<td>0.50</td>
<td>0.05</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Farmers in group CE(3) live in areas more affected by erosion and have greater participation in the soil conservation program than the other two groups showing that technical assistance programs have been having a significant effect on adoption of soil conservation practices. In respect to cognitive variables, higher awareness of the limits of technologies and soil to provide resilience to erosion together with higher perceptions of i) risks associated to agricultural activities, and ii) benefits associated to soil conservation and awareness, have a positive effect on adoption. More specifically, farmers in group CE(3) (who are mainly agriculturists) show significantly higher risk perception of the immediacy of pasture impacts on erosion than do groups CE(1) and CE(2). Similarly, as opposed to the other two groups, group CE(3) is more concerned with the longer-term benefits of erosion control (i.e. for future generations) as well as
with a perspective that public administration should be paying for removing sediment from rivers. On the other hand, with respect to $CE(2)$, $CE(3)$ farmers show significantly lower values of index $B_i$ (i.e. positive beliefs on the role of technology and soil resilience to reduce the adverse effects of soil management).

The group with medium conservation effort $CE(2)$ is composed of a significantly larger proportion of farmers dedicated to dairy-farming with a lower participation in soil conservation programs. Farmers in this group show a significantly lower perception of the risk associated with human activities (i.e. agriculture and dairy-cattle farming) than farmers in the other two groups, and generally less concern over the public and private benefits of erosion control (i.e. $V_1$ and $V_2$). Consistent with the findings of the discriminant analysis, risk perception of impacts of agricultural activities on erosion and values regarding short-term benefits of erosion control have an inverse relationship with conservation efforts. Indeed, farmers with the lowest level of conservation effort $CE(1)$ showed higher risk perception of the impacts of agricultural activities on erosion ($R_1 = \text{agricultural risk}$) than farmers in $CE(3)$ and $CE(2)$ Farmers in group $CE(1)$ also showed higher concern with respect to groups $CE(2)$ and $CE(3)$ for the private aspects of soil conservation and the importance of short term benefits of agricultural activities against the longer term benefits of erosion control ($V_1 = \text{“private benefits“}$). Deeper analysis of the data on tenure and production activities will help to illustrate this finding. In group $CE(1)$ we find mainly horticulturalists as opposed to the other two groups (where horticulturalists and dairy-farmers are more evenly represented). A comparison of the average farmland owned by these two types of producers shows that horticulturalists own smaller plots ($p_{\text{Kruskal–Wallis}} < 0.005$) in which the opportunity cost of soil conservation might be perceived as being higher. Small-scale farmers, dealing with short-term production cycles, such as is the case of horticulture in the area, however, might show awareness of soil degradation but feel that private benefits are more important in the short run.

To further explore these hypotheses we ran a non-parametric test to compare mean values of cognitive indexes accounting for farmers’ groups $CE(i)$ and also accounting for size of farm owned. We thus categorized the variable “total farmland” available to producers into two separate classes; namely, those owning less than 10 ha ($n = 16$) and the others ($n = 40$). For smaller landowners, the group with lower conservation efforts $CE(1)$ has a significantly higher
score for beliefs about “critical soil conditions” ($p_{Kruskal-Wallis} < 0.05$) and “private benefits” compared to the other two groups ($p_{Kruskal-Wallis} < 0.05$). Finally, the producers in group $CE(3)$ show greater concerns about “public benefits” ($V_2$) aspects than the other two groups of farmers.

3.5 Discussion

The results of our analysis reject the hypothesis that farmers’ voluntary soil conservation efforts are not influenced by the interaction of cognitive and socioeconomic variables, keeping with the findings of previous research in the region (Foster, 1994). Factor analysis allowed the identification of the most important cognitive aspects that influence soil conservation decisions and the construction of consistent indexes. The multivariate discriminant analysis indicates that the group of farmers with lower conservation effort is positively correlated with cognitive variables. This contrasts with the group showing higher conservation effort (i.e. group $CE(3)$), where there is mainly a positive correlation with socioeconomic variables and exposure to erosion risk. This suggests that, together with the promoted direct payments, a complex set of factors need to be considered in designing conservation programs aimed at promoting adoption of appropriate soil management practices.

Our results indicate that complex interactions among cognitive and socioeconomic dimensions influence significantly farmers’ decisions on soil conservation. However, comparison with other studies in the Central American region can only be limited to socioeconomic and some institutional variables (e.g. presence of soil conservation programs) while cognitive variables have been overlooked. More specifically, from an economic perspective, farmers with lower conservation effort are also those cultivating smaller farmlands, which might entail the perception of higher opportunity costs in the implementation of soil conservation practices. This is supported by the results of the economic analysis of soil conservation practices in the close Tierrablanca watershed in Costa Rica (Cuesta, 1994) where results indicate that conservation practices have negative returns also due to the proportion of productive farm land dedicated to conservation (i.e. small farms having higher opportunity cost). Our results also support the finding of Cuesta (1994) and Vasquez and Santamaria (1994) by suggesting that institutional programs promoting technical assistance should be strengthened given their positive effect on adoption of soil conservation practices. Our findings show, however, that cognitive variables also
influence the extent to which individual farmers decide to implement soil conservation practices. Farmers’ evaluation of the benefits of soil conservation for agricultural production trades off against the costs they attach to erosion control. Their judgment on the costs of soil erosion control and on its benefits appears to be conditioned by their specific context, such as the extent and tenure regime of the land cultivated. Smaller holdings are associated with horticulturalists that have less land available for the implementation of conservation practices and, moreover, are more concerned with short-term income needs, although they score higher on awareness of risks and causes of soil erosion in the area.

Farmers in our sample with lower conservation efforts show a significantly higher perception of the risk of agricultural activities. This finding contrasts with those of Weber et al. (2001), who reported that actual exposure and awareness increase proactive behaviour. Additionally, the “availability heuristic” paradigm (Tversky and Kahneman, 1974) may also be playing an important role in farmers’ soil conservation behaviour. Indeed, the inverse relationship between risk perception of the impacts of agricultural activities on erosion and conservation efforts suggests that farmers may underestimate the consequences of their agricultural activities on erosion. In other words, daily experience with erosion might give the illusion of control and/or smaller losses. Moreover, as discussed Bewket (2007), while awareness of risk and its causes can influence farmers’ intentions to implement soil conservation practices, its actual adoption depends on socioeconomic and institutional aspects.

The most educated farmers do not show strong beliefs regarding the soil’s capacity to recover or the ability of science and technology to overcome erosion problems ($B_2$) and they reveal higher conservation efforts. These findings contrast those of Abreu (1994) whom found no significant effect of education on adoption level of farmers in the close watershed of Tierrablanca. Educated farmers in our sample show awareness of the importance of implementing soil conservation practices, understanding that soil productivity can be degraded if appropriate actions are not initiated. These findings confirm those of other authors, in keeping that education is related to knowledge of consequences of soil management practices and of alternative solutions, which in turn influences behaviour (Carlson et al., 1977; Ervin and Ervin, 1982; Traore et al., 1998; Mbaga-Semgalawe and Folmer, 2000; Lambert et al., 2007). In line with this same argument, technical
assistance programs improving farmers’ understanding of erosion causes and alternatives available can improve their chances of adoption (Traore et al., 1998).

3.6 Conclusions

This article provides new perspectives on the relationship between the perception of climate change risk posed to farm soils and the adoption of conservation practices. The model we used enriches our understanding of the complex interactions among socioeconomic and cognitive variables by showing how these interactions differentiate among specific groups of farmer types. Farmers show a low awareness of the risks posed by climate-change-related extremes to their farm soil, although they show high concern with the impacts of human activities. Additionally, our results suggest that soil conservation programs should strategically consider promoting improvement of understanding of the causes, the on-site and off-site consequences, and the limitation of soils and technological solutions to provide resilience to erosion. This might improve understanding on the urgency to take action given the potential intensification of erosion-causing extreme events in vulnerable watersheds and increase the probabilities of larger self-motivated adoption of soil conservation practices.

3.7 References


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4.1 Negotiation analysis for mechanisms to deliver ecosystem services: a value-focused bargaining structure to achieve joint gains in the provision of Soil Regulation Services

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Abstract

Direct payment schemes have been discussed in the literature as economically efficient means to create and maintain the institutional and practical linkages to reduce degradation of ecosystem services (ES). However, evidence suggests that the nature and structure of institutional mechanisms is fundamental to the efficacy and efficiency of outcomes, yet has received little attention.

Linkages between ES producers and consumers require bargaining about the characteristics of mechanisms for cooperation at a given location. In this paper, we introduce negotiation analysis informed by both stakeholders’ value-based information and technical knowledge as a means of structuring negotiation about mechanisms for maintaining ES. We use a case study in a watershed where upstream farmers and downstream hydropower might benefit from the design of a mechanism to foster the provision of soil regulation services. We identify the values of producers and consumers to understand their views on important means and ends in decisions about ES provisions. We complement this value-based information, with literature on alternatives for soil conservation programs. We, thus, create a negotiation template to identify bargaining opportunities and thus the potential for better outcomes. Our results show that there is convergence of preferences on the important aspects of the mechanisms between the two stakeholders. This provides opportunities for joint gains in the provision of soil regulation services that can provide more resilience to climate change in Costa Rica, which is expected to bring more erosion due to more intense rainfall.

Keywords: Negotiation analysis, decision analysis, ecosystem services, soil conservation

4.1 Introduction

The Millennium Ecosystem Assessment documents the massive growth in human demands for services from ecosystems over the last four decades and reveals that over two thirds of global
ecosystem services (ES) systems are in decline (MEA, 2005). It provides a typology of diverse ES produced within linked human and natural systems\(^7\). ES involving water resources are often produced or regulated at upstream locations and consumed downstream (Kosoy et al., 2007). This is the case of soil regulation services (SRS) whose provision is influenced by actors such as upstream farmers affecting the quantity of sediments in rivers and downstream beneficiaries of SRS such as hydropower dams (Southgate and Macke, 1989). Often these groups are spatially and administratively separated, do not have a history of interactions, and lack an understanding of the potential joint gains if upstream producers had the interests of downstream consumers more directly in mind, and had resources to address those interests (Ison et al., 2007).

The mechanism most widely employed to link producers and consumers of ecosystem services is direct (or indirect) Payment for Ecosystem Services (PES) from direct beneficiaries (or governments) to providers. Researchers have provided typologies of PES compared to other policy instruments (Engel et al., 2008), and considered ways to improve economic (Ferraro, 2008), environmental (Wunsch et al., 2008) and social (Pagiola et al., 2005) performance of PES schemes. The underlining reasoning of PES schemes puts emphasis on the potential for efficiency gains by making externalities internal to the decisions of ES providers. Yet many social factors other than opportunity costs influence the decisions of actors to alter land uses, as confirmed by a comparative study in the Central American region which showed that producers generally failed to meet their opportunity costs in efforts to provide ES (Kosoy et al., 2007).

Hence a broader form of bargaining, in which multiple objectives are considered on both sides of ecosystem service production and consumption, built on an understanding of how upstream producers could be motivated to provide services for downstream beneficiaries, would be highly relevant in designing mechanisms for ES provision. Previous experience in cooperative management of natural resources has shown that formal and informal institutional arrangements are fundamental to outcomes (Dietz et al., 2003). Yet how mechanisms are to be built in order to foster ES provision has received relatively little attention (Wilson and Horwath (2002) and de Groot and Herman (2009), are exceptions). This paper attempts to address that gap through

\(^7\) These include: provisioning services such as food, water, timber, and fiber; regulating services that affect climate, floods, disease, wastes, and water quality; cultural services that provide recreational, aesthetic, and spiritual benefits; and supporting services such as soil formation, photosynthesis, and nutrient cycling (MEA, 2005:9).
attention to bargaining for design of mechanisms for provision of ES that are mutually agreeable to the interested parties. The standard normative approach to conflict and negotiation is game theory, which seeks normative equilibrium solutions given known alternatives, constrained objectives, and known payoffs. Here we adopt a more behaviourally-oriented, prescriptive approach to analysis of bargaining contexts, with an emphasis on decision structure and process, referred to as negotiation analysis (Young, 1991; Sebenius, 1992; Raiffa et al., 2002).

Costa Rica has experience with PES through its recently established system of paying land holders for maintaining or regenerating forest cover (Pagiola, 2008). The performance of PES schemes in Costa Rica has been the subject of much discussion, review and evaluation (Miranda et al., 2007; Sanchez-Azofeifa et al., 2007; Wünscher et al., 2008). In this paper, we consider another context for ecosystem service provision in Costa Rica, involving farmers who are horticulturalists and dairy-cattle producers on steep, cool, erosion-prone volcanic slopes in the Birris watershed, high above reservoirs that are important for national hydropower production. We use the context of potential SRS provision through soil erosion control to develop a bargaining framework for a mechanism to foster ES provision, in which the downstream power producers could provide incentives or other kinds of support. Improving soil erosion control would benefit two electric utilities by reducing the amount of sediment in rivers, (the Administrative Board of the Electric Utility of the city of Cartago (JASEC) and the Costa Rican Institute for Electricity (ICE)), as well as providing on-site benefits for the farmers engaged in service provision (Pimentel et al., 1995; Guo et al., 2000; Wossink and Swinton, 2007).

This paper has two related objectives. One objective is to demonstrate the relevance of negotiation analysis for complex bargaining contexts such as developing mechanisms for ES provision. A second objective is to provide a structure for the negotiation space among stakeholders. We build a template to guide bargaining in the design of mechanisms to accomplish linkages among producers and consumers. ES provision in the Birris watershed is used as an

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example. The next section provides an introduction to negotiation analysis, and the particular characteristics of ES provision that make the approach especially relevant. Section 3 provides more details of the Birris ecosystem services context relevant for negotiation analysis. Section 4 discusses methods used to gather information for this research. Section 5 includes results, in terms of a negotiation template and its evaluation by farmers and the electric company. Section 6 provides conclusions.

4.2 Negotiation Analysis and Its Relevance for ES

Collaborative planning for complex human-natural systems necessarily relies on negotiation (Innes and Booher, 1999, Fisher et al., 2009); yet how to structure negotiations in such contexts merits greater attention. Negotiation analysis could potentially be a valuable tool for building the basis for agreement among conflicting interests that characterize these contexts (de Groot and Hermans, 2009). Negotiation analysis might be referred to as both “game theory minus” and “decision analysis plus” (Sebenius, 1992).

“Game theory minus” indicates that while it deals with the same broad kinds of issues, negotiation analysis does not entail the examination of well-defined games with known rules, players and payoffs, in a search for normative equilibrium solutions, as in game theory. Rather it is asymmetrically prescriptive/descriptive in orientation, providing prescriptive guidance on negotiation decision process for one actor, based on descriptions of expected behaviour by the other party⁹. Negotiation analysis has a Bayesian (subjectivist) perspective on uncertainty and information, and adopts bounded rationality rather than normative optimization as the guiding assumption regarding behaviour of participants. It recognizes the benefits of full and open information exchange in negotiation¹⁰.

“Decision analysis plus” indicates that negotiation analysis involves situations in which agreement among multiple parties is required, providing the potential for joint gain, which are more demanding contexts than analysis for a single decision maker. It draws on the decision analytic process (Hammond et al., 1999) in terms of a series of iterative steps involving value perspectives

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⁹ In this paper, we seek to provide support and analysis for both sides in potential negotiations, so its orientation is prescriptive, built on descriptive understanding for both sides.

¹⁰ Raiffa et al. 2007 refers to the benefits of “full, open, truthful exchange” (FOTE) as an ideal in reaching better agreements within negotiation analysis.
and technical information, with a focus on values of the parties to the negotiation as a basis for constructing and comparing alternatives. Raiffa (1982) first explicitly considered how the concepts and methods of decision analysis for a single decision maker could be broadened to serve as the basis for both an art and science of negotiation. In the early 1990s, a survey article (Sebenius, 1992) and edited book (Young, 1991) delineated negotiation analysis as a new perspective on conflict and bargaining, and provided concepts and applied examples to guide these efforts. A recent book by Raiffa and colleagues (2002) further develops negotiation analytic concepts and practice. Drawing on these sources, key aspects of negotiation analysis that are particularly important for ES include the following points.

Creating or changing the negotiation. ES provision is a context in which the potential parties (i.e. producers and consumers) to a prospective negotiation may be spatially distant, of different class or ethnic backgrounds, and operate in entirely different institutional or governance contexts. They may have little or no knowledge of the potential gains that could be achieved for consumers if producers managed ES provision differently. Hence the precepts of a game with known parties, known rules and known payoffs for well-defined alternatives are not relevant. In ES provision, there is a need to begin by creating the context for a negotiation, or perhaps altering existing arrangements, rather than learning through repeated, well-defined games.

A focus on the values of the negotiating parties. The values of the parties are the reason why they may wish to negotiate and achieve joint gains. Values for ES provision may be complex and involve different concerns for different groups (Ison et al., 2007). For example, the work by Kosoy and colleagues (2007) shows that multiple objectives necessarily matter for ES provision. While almost any approach to decision-making or negotiation calls for attention to values, decision analytic approaches have well-developed and effective methods to characterize values. Keeney (1992) discusses value-focused thinking as a framework for characterizing values for any decision context, including multi-party negotiation, (see Section 4).

Creating attractive alternatives that expand the benefits, and are more likely to facilitate agreement. Negotiation analysis built on value-focused thinking attempts to create new, more attractive alternatives that are both more likely to be implemented, and more likely to address the full range of objectives among the parties (Keeney, 1996). In this manner, the parties have an opportunity to expand the potential benefits of agreement, rather than only focusing on claiming
benefits\textsuperscript{11}. Reaching agreements based on relevant stakeholders’ values can support the design of more socially-stable management strategies (e.g. building trust and mutual learning) that are important for longer-term adaptive solutions needed in ES protection (Innes and Booher, 1999). How the alternatives are to be constructed is a particularly significant question involving technical understanding, knowledge of relevant values, and creativity in linking the two. Keeney stresses the importance of values as a guide to design of alternatives, and differentiates among values for the outcomes (the ultimate ends of interest, such as ES provision, costs and so forth) versus values for the design of the process.

**Attention to the alternatives to a negotiated agreement.** A negotiator’s best alternative to a negotiated agreement (BATNA) is widely seen as an important indicator of the value of an alternative and thus negotiation strategy. In the case of ES provision, the BATNA may be the status quo. Alternatively, there may be recognition that competition for ES is increasing in many locations, and global change processes, particularly climate change, may well limit the extent to which the status quo of ES provision can continue. Understanding that the status quo may not be viable over the medium to long term provides more incentive to reach a negotiated agreement for ES provision.

4.3 ES provision in the Birris Watershed

The Birris watershed descends from the slopes of Irazu Volcano above the central valley of Costa Rica in Cartago province. The watershed is characterized by rich and deep soils (i.e. andosols) that have attracted many farmers to cultivate vegetables on small to medium sized plots for local markets. Over 300 producers work in the watershed, often on very steep slopes, in locations where annual precipitation is 2325 mm (Marchamalo, 2004). Extreme precipitation events have increased over the last forty years (Aguilar et al., 2005) and are expected to continue to increase as a result of climate change (Magrin et al., 2007).

A research project with many regional partners has investigated several aspects of SRS provision in the Birris watershed, and its links to hydroelectric facilities downstream. These facilities are greatly affected by siltation, which is expected to worsen in the future under changing climate conditions.

\textsuperscript{11} Sebenius (1992) provides a discussion of the tension between creating and creating value in negotiation analysis, and identifies what he terms the “negotiator’s dilemma”, in contrast to the Prisoner’s dilemma.
conditions. Both JASEC and ICE operate electrical generation facilities downstream from the Birris watershed, for which costly dredging and flushing of silt, or replacement of energy powered by diesel generators, or both, are needed to address power losses due to siltation in reservoirs. Interviews indicated that, in 2006, more than $ four million US in foregone power production and other direct costs were spent by the utilities to flush sediments from their reservoirs.

The situation in the Birris watershed illustrates several of the points made in the previous section about the nature of ES provision and why negotiation analysis is relevant. The utilities have no direct experience in building a large scale program to provide incentives or other support to farmers for soil conservation practices. Neither ES providers nor beneficiaries in the Birris watershed have a clear understanding of the need to bargain or the potential benefits of bargaining. They operate at different scales of governance, and different spatial scales, and require new institutional mechanisms in order to address joint interests. While farmers in the watershed understand erosion processes, they have limited awareness of the effects of erosion on downstream hydropower facilities and of how the effects of climate change (in making rainfall more intense) can affect their own farm soils.

National law requires electric companies to pay a tax to the Ministry of Environment MINAET for water use. A part of these payments can be destined to fund watershed management activities (Ponce, 2006). The two downstream hydropower companies, JASEC and ICE have initiated some small scale programs to i) increase awareness, ii) encourage voluntary erosion control, and, iii) provide some learning opportunities for soil conservation practices. Yet the companies have limited understanding of farmers’ objectives, and the constraints they face. In addition, neither farmers nor the electric companies have much experience with the costs and structure of soil conservation mechanisms, or their benefits in terms of actual changes in the rates of erosion.

Although ecosystem services may seem to be unusual as context for a negotiation analysis, it is highly relevant application (de Groot and Hermans, 2009). Writers concerned with providing negotiation advice often speak of the need to negotiate about the process as well as substantive outcomes of ES conservation schemes (Fisher et al., 1991). The structure of the negotiation in what follows is more along the lines of institutional design than a more standard textbook negotiation problem, such as negotiating the price of an asset; nevertheless it is a new and potentially widely applicable context.
4.4 Methods

Negotiation analysis requires construction of a negotiation template (Raiffa et al., 2002), built on an understanding of motivations, objectives, and characteristics of acceptable alternatives, identified separately for each of the negotiating parties. The overall procedure used to develop the negotiation template in this study is shown in Figure 1.

![Figure 1: Research method: steps to build and evaluate the negotiation template for the design of mechanisms to improve ES provision.](image)

Here we adopt Keeney’s value-focused thinking (VFT) as one important basis for creating this template (Keeney and Raiffa, 1991; 1993). VFT involves a process of clarifying values important to decision makers and interested parties. That information can then be used to identify requirements of additional information for decisions and for serving as a basis for creating more attractive alternatives (Keeney, 1992; Gregory and Keeney, 1996). VFT has had wide application in a variety of contexts, including environmental management, business strategy, defence, engineering, and planning, particularly for citizens’ involvement in complex decisions (McDaniels et al., 1996) and recently in negotiations for PES (de Groot and Hermans, 2009). Keeney and Raiffa (1991) have discussed value-focused thinking for both parties in a negotiation as a fundamental step in developing a decision template, which is an important step in negotiation analysis.

Our method is informed by two closely related approaches, namely: discourse-based and Area Development Negotiations. The first approach involves the use of small groups of stakeholders’ representatives to deliberate on relevant aspects of ecosystem services, bringing to the discussion their values, attitudes and beliefs (McDaniels et al., 1999; Wilson and Howarth, 2002).
The second approach includes a sequence of steps to build understanding of the case through interviews, focus groups, expert information and experiential encounters with the case study as a way to identify common strategies in the presence of divergent interests (Scholz and Tietje, 2002).
4.4.1 Data Acquisition (Step 1)

Steps 1 is concerned with eliciting, by interviews and focus groups with each stakeholder, value perspectives and other related cognitive information relevant for the decision context (details in section 4.1.1 and 4.1.2).

The discussions with actors were structured to elicit the participants’ values for actions and decisions regarding watershed management efforts to reduce erosion. To elicit values we asked stakeholders to comment on what is important to them regarding direct payments to farmers as a means to foster conservation in upstream farms, drawing on the analogy of an existing PES scheme in Costa Rica (Pagiola, 2008). Specific questions elicited their views on implementing a scheme for soil conservation in productive farms and the associated constraints. We asked questions on what makes ideal alternative solutions and their expected benefits in order to elicit their views on alternative strategies. The focus group discussions were transcribed and analyzed to identify and structure key objectives in order to use them as inputs in the construction of the negotiation criteria on a SCP.

4.4.1.1 Data from farmers

Interviews. In June 2007, individual semi-structured interviews were conducted with producers \((n = 50)\) from the Birris watershed, selected randomly from the producers’ census of the local agricultural extension office. We completed a comprehensive review of available farm practices for soil conservation and their adoption in the area based on existing documents in the agricultural extension office. In part, this review helped identify key barriers and opportunities for the successful implementation of conservation practices in the Birris watershed. The interview instrument included questions to elicit farmers’ perceptions on the health of their soil and whether they believe they face problems with soil degradation or erosion. We also included questions to capture their understanding of erosion control processes using the mental model method discussed in Morgan et al. (2002)and open-ended questions about the factors constraining or promoting the implementation of soil management practices (detailed results can be found inVignola et al., 2009).
Focus group. To build on the individual interview results, we conducted a focus group with representatives of producers’ associations in the office of the Birris agricultural extension service in order to discuss the objectives for soil conservation programs. The participants included representatives of a large local cooperative of producers, a member of a national producers’ association, a member of a small producers’ association, and an independent producer whom is a local lead producer promoting soil conservation on producers’ farms. We began with an open discussion on the state of soil erosion in the watershed and the factors that make it vulnerable to erosion (i.e. climate, land use practices and infrastructure). Next, we explored past experiences regarding conservation of SRS and the alternatives that have been considered, in conjunction with incentives that would be helpful to foster their adoption. We then employed methods discussed in Keeney (1992), and related papers, to elicit concerns, constraints, and value perspectives.

4.4.1.2 Data from JASEC

Interviews. A series of informal discussions was held with different individuals working within the JASEC-Birris hydropower production system. Those interviewed included the vice-president, the manager of the hydropower facility, and the individuals responsible for watershed operations and for sediment monitoring in the dam. The broad intent was to learn about system operations, the effects of siltation on operations, and the utility’s interests and concerns in considering possible ES programs to address siltation. We again followed methods outlined in Keeney (1992) to structure the discussion, as a basis for clarifying the fundamental ends and means to achieve the overall goal of a SCP.

Focus Group. To build on the results of the interviews, a focus group was held with four senior officials from JASEC, including: the vice-president; the coordinator of the Electric Operation Unit; the director of the Special Project Unit; and the coordinator of an environmental education program in the Birris watershed. Participants discussed on current soil conservation activities and what are the characteristics of ideal alternatives to improve SRS provision. Positive and negative aspects of current user-financed PES programs and potential alternatives helped characterizing JASEC’s means and ends to achieve a desirable SCP.
4.4.2 Synthesis for template building (Step 2)

Step 2 involves synthesizing and analyzing transcribed interviews and focus group discussions which complementary information for evaluation of natural resources (Kaplowitz and Hoehn, 2001). Here we used the WITI (“Why is that important?”) method of questioning in interviews, as discussed in Keeney (1992) and Clemen and Reilly (2001), to distinguish among ends and means relevant for the two groups of decision makers (farmers and the electric utilities). For a negotiation template, the ends or fundamental objectives are used as the basis for criteria to compare and evaluate alternatives from each party’s viewpoint, while the means are used to create better, more attractive alternatives. Based on this information we prepared a draft set of objectives, and an objectives network, also called a means-ends network (Keeney, 1992). Step 2 also involves creating attractive alternatives to be addressed in the negotiation. Gregory and Keeney (1994) and Keeney (1992) articulate how stakeholder values can be used to help create more attractive alternatives through a process of considering and building creative linkages among means and ends.

This value-oriented information on alternatives was complemented by expert-based sources. We draw on literature regarding watershed management and soil conservation mechanisms to identify various aspects or components of a mechanism for soil conservation, as well as the alternative options available. We use an approach referred to as a strategy table (Clemen and Reilly, 2001) to graphically communicate the structure of the alternatives, which includes four separate components (discussed below) and several sub-alternatives. These sub-alternatives can then be combined in various ways to create separate strategies of a mechanism for fostering ES provision, which are the alternatives considered in this template. In other words, combining sub-alternatives from each of the four components provides the basis for an array of different strategies, which could serve as the basis for negotiation and ultimately agreement among the two parties to create and structure a soil conservation program.

4.4.3 Verification and evaluation of alternative strategies (Step 3)

In Step 3, the two groups are asked, in two separate focus groups, to first verify and then evaluate the alternatives under each of the components of mechanism design. We verified, following Habron et al. (2004), the diagrams we drew based on stakeholders’ consultations in
order to confirm we had adequately captured participants’ perspective on the problem. Hence in each of these meetings, our interpretations of the results from earlier meetings were reviewed and verified by each party to the negotiation.

After verification by the two groups, the elicited ends can serve as the objectives or evaluation criteria for each group in the decision context. The evaluation process is akin to eliciting the ‘zone of bargaining’ (Raiffa et al., 2002) for each of the components. The two groups were also separately asked to identify which sub-alternatives under each of the four components of strategies are acceptable from their viewpoint. The intent of this process is to define the negotiation space, or areas of potential agreement, that could help shape and direct the subsequent negotiation process.

We did this by asking the individuals in each group of participants to review the specific components, and sub alternative under each component, as presented in a workbook we had previously prepared. Participants were asked to indicate which alternatives were acceptable to them (a task similar to approval voting; McDaniels and Thomas, 1999). We also asked participants to indicate which alternative would be most preferred in negotiation. We tried to ensure the questions were understood by all participants. The judgment tasks were kept as simple as possible to facilitate participation, but elicited important information regarding initial perspectives on aspects of future negotiations.

4.5 Results

4.5.1 Objectives of negotiating parties

4.5.1.1 Farmers

The meeting with farmers \((n = 8)\) was held at the Birris agricultural extension office in February, 2009, and included leaders of farmers’ associations and individual producers. Figures 2 presents

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12 Objective statements require a decision context, an object, and a direction of preference (Keeney, 1992). For example one objective is stated as stated as fostering or improving (direction of preference) farm incomes (object), in the context of implementation of a soil conservation program (context). Sub-objectives (e.g. short term (less than two years) and long term (two years or more)) further specify the objective statement.

13 Note that because the components are largely separable, they can be considered and negotiated individually as part of a large agreement.

14 The Birris agricultural extension officer attended the final workshop to answer questions and provide help to farmers who had difficulty reading the workbook.
the objectives of farmers regarding the nature of a desirable mechanism for an ES program, as derived from the methods discussed in Section 4 and verified in the final meeting with farmers. On the left side of the diagram are various means raised in discussions, while the right side shows the ends or fundamental objectives important to farmers in terms of mechanism design. The objectives listed on the right side reveal the characteristics of the ideal mechanism from the farmers’ viewpoints, which include: 1) *provide incentives for soil conservation*, 2) *ensure equity in distribution of incentives*, 3) *promote learning and adaptive management* (i.e., about soil conservation practices) and 4) *achieve the overall objectives of a SCP* (i.e. that work well for both farmers and JASEC in addressing soil conservation). There may well be tradeoffs among these objectives, or no alternatives that satisfy all at once, so care is required in designing and evaluating the alternatives.

![Diagram showing farmers' network of means-ends objectives for a desirable soil conservation program.](image)

*Fig. 2. Farmers’ network of means-ends objectives for a desirable soil conservation program.*
The means on the left side of Figure 2 show key aspects for creating attractive alternatives to achieve the overall goals of soil conservation in the watershed from farmers’ perspectives. Note that many of the means for designing a desirable SCP relate to fundamental objective of achieving program success. In other words, one criterion for designing the mechanism is whether it is likely to achieve the fundamental ends of program implementation.  

4.5.1.2 JASEC

The meeting with the Executive Board of JASEC \( n = 5 \) was held at their corporate administrative office on March, 2009. Participants included all those who took part to the focus group sessions for step 1 plus the JASEC responsible for sediment management and monitoring. Fig. 3 (parallel in structure to Fig. 2) addresses the objectives of JASEC for the design of a mechanism for fostering SRS provision. Again, we drew on the results of interviews and focus group with JASEC to distinguish ends from means and then confirmed these results in the JASEC final workshop.

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15 Similar linkages between fundamental objectives for the process, and for the actual implementation, are found in Keeney, McDaniels and Ridge-Cooney, 1996
In Fig. 3, in the right column, we find four objectives that are related to the fundamental achievements of a Soil Conservation Program that show concerns in different dimensions. For example, JASEC is concerned with minimizing investment needs by targeting areas for SRS provision providing higher return in investments. Moreover, they expressed the wish to improve knowledge on costs and benefits of supporting a SCP while maintain a good public image through the promotion of a Soil Conservation Program. A comparison between Fig. 2 and 3 shows that the two sets of parties to the negotiation share some objectives, and also have some differing concerns over the aspects of a desirable SCP. That is not unexpected, and it is helpful to make these differences explicit (Sebenius, 1992).

4.5.2 Alternatives as strategies across several dimensions
The alternatives (which are strategies composed of sub-alternatives under various components) considered for the negotiation template are based on the complementary use of the structured means-ends networks in Fig. 2 and 3 and expert-based literature. Table 1 shows the four components important in designing a mechanism for a soil conservation program, the sub-alternatives under each component, and the information sources used to identify them. The four components of designing a mechanism for ES provision (Engel et al., 2008; Wunder et al., 2008): include (i) Selection of producers to receive SCP support, (ii) the Nature of support that the SCP delivers to producers, (iii) the Nature of the contract establishing a formal linkage between providers and beneficiaries of SRS, and, finally, (iv) Who should be intermediary between the two parties in the SCP.
Table 1. Components of alternatives drawn from participants and expert-based literature.

<table>
<thead>
<tr>
<th>Component</th>
<th>Alternatives</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selection of producers</td>
<td>All over the watershed</td>
<td>Participants (farmers, utilities)</td>
</tr>
<tr>
<td></td>
<td>Bid through auctions</td>
<td>Ferraro, 2008.</td>
</tr>
<tr>
<td></td>
<td>High priority areas</td>
<td>Goldman et al., 2007.</td>
</tr>
<tr>
<td></td>
<td>Socioeconomic status</td>
<td>Pagiola et al., 2005.</td>
</tr>
<tr>
<td></td>
<td>Random</td>
<td>Participants</td>
</tr>
<tr>
<td>Nature of support</td>
<td>Credit</td>
<td>Participants</td>
</tr>
<tr>
<td></td>
<td>de-taxation</td>
<td>Participants</td>
</tr>
<tr>
<td></td>
<td>Technical assistance</td>
<td>Participants</td>
</tr>
<tr>
<td></td>
<td>Direct Payment</td>
<td>Engel et al., 2008; Wunder et al., 2008; Pagiola, 2008.</td>
</tr>
<tr>
<td></td>
<td>Rigid</td>
<td>Bougherara and Ducos, 2006.</td>
</tr>
<tr>
<td></td>
<td>None</td>
<td>Participants</td>
</tr>
<tr>
<td>Who should be intermediary</td>
<td>Each single producer</td>
<td>Participants</td>
</tr>
<tr>
<td></td>
<td>Agricultural extension office</td>
<td>Participants</td>
</tr>
<tr>
<td></td>
<td>Watershed committee</td>
<td>Participants</td>
</tr>
<tr>
<td></td>
<td>Producer’s association</td>
<td>Participants</td>
</tr>
</tbody>
</table>

The sub-alternatives under each component were derived from both stakeholders’ and expert-based literature. For example, the sub-alternatives under the component “Selection of producers” are the result of both actors’ consultation and literature. Here, farmers indicated concern over “Characterizing farmers by socioeconomic characteristics” as a prerequisite of targeting incentives in equitable manner while JASEC expressed concern over focusing selection of farmers in “High priority areas”. Both these sub-alternatives are complemented by the sub-alternative to select farmers by an auction-bidding process (Ferraro, 2008). On the other side,
based on interviews with farmers and JASEC we could identify that the current strategy for selecting farmers for support is at “Random”\textsuperscript{16}.

Similarly, for the component “\textit{Nature of support}”, literature widely supports the use of “\textit{Direct payments}” to support farmers’ efforts in soil conservation (Engel et al., 2008). Our interviews and focus groups additionally identified the potential use of indirect economic incentives, such as removing taxes on agricultural inputs (i.e. “\textit{De-taxation}”), “\textit{Credits}”\textsuperscript{17} for soil conservation, and the provision of “\textit{Technical assistance}”\textsuperscript{18}. For the component “\textit{Nature of the contract}” to formalize agreement between the negotiating parties, we found a status-quo alternative (i.e. “\textit{No contract}”) from stakeholder consultations. Additionally, two other sub-alternatives from the literature (Bougherara and Ducos, 2006), namely “\textit{Flexible}” (defined annually) or “\textit{Rigid}” contracts (fixed over a period of several years) were included to identify potential trade-offs between the concerns of JASEC and farmers. More specifically, farmers attempt to maintain flexibility, to allow ongoing adaptation to changing markets and climate conditions; therefore they are likely more attracted by the possibility of flexible contracts. For JASEC, rigid contracts might be preferable, to ensure that practices implemented at the start of a contract period are maintained throughout the duration of the contract (i.e. even in the face of changing market or climate conditions).

Finally, the alternatives for ”\textit{Who should be intermediary}” reflect concerns over which institutional entity is or should be entitled to support activities such as contracting, monitoring and following-up of soil conservation practices. While entities such as “\textit{Agricultural extension office}”, “\textit{Producers’ associations}” and “\textit{Individual producers}” are known to both groups, “\textit{Watershed committee}” is familiar only to JASEC whose watershed management plan includes a mandate to create such a committee. Sub-alternatives under the component “\textit{Selection of farmers}” and “\textit{Nature of support}” are not mutually exclusive, and could be combined. For example, for “\textit{Selection of producers}”, targeting farmers in priority areas and letting them compete through auctions could both be selected. Similarly, for ”\textit{Nature of support}”, providing

\textsuperscript{16} Although, technical assistance is focusing on broadly-defined areas with serious erosion, there is no established process for defining priority areas.

\textsuperscript{17} Credits were mentioned in reference to past experience in the area where banks were providing low-rate loans to selected producers using a specific variety of low-impact potato crop.

\textsuperscript{18} Technical assistance was defined to include on-going soil conservation programs. Extension officers visit farms periodically to advise on and monitor farmers’ implementation of soil conservation practices. Also training is provided if new techniques are introduced.
“Direct payment” could be combined with “Technical assistance”. On the other hand, alternatives under “Nature of contracts” and “Who should be intermediary”, sub-alternatives are mutually exclusive.
4.5.3 Acceptability, preferred alternatives and zones of bargaining

In the evaluation phase, participants in the focus group used a workbook organized to evaluate the components one at a time. Fig. 4 summarizes the consultation results of the evaluation process in a similar way as presented in Scholz and colleagues (2007). In separate meetings with both farmers and JASEC, we elicited, which of the alternatives under each component would be acceptable (i.e. more than one sub-alternative could be selected), and which was most preferred. The figure shows alternatives acceptable to at least some of the farmers, to some representatives of JASEC, and to both. To avoid an arbitrary aggregation rule, we report the percentage of participants in agreement, in each box of the table.

<table>
<thead>
<tr>
<th>Selection of Producers</th>
<th>Acceptable to farmers only</th>
<th>Acceptable to both</th>
<th>Acceptable to JASEC only</th>
<th>Not acceptable to both</th>
</tr>
</thead>
<tbody>
<tr>
<td>All over the watershed</td>
<td>12.5</td>
<td>75</td>
<td>High priority areas</td>
<td>Socioeconomic status</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Random</td>
</tr>
<tr>
<td>Bid through auctions</td>
<td>12.5</td>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nature of support</th>
<th>Acceptable to both</th>
<th>Acceptable to JASEC only</th>
<th>Not acceptable to both</th>
</tr>
</thead>
<tbody>
<tr>
<td>Credit</td>
<td>12.5</td>
<td>75</td>
<td>Technical assistance</td>
</tr>
<tr>
<td>De-taxation</td>
<td>12.5</td>
<td>0</td>
<td>Direct payment</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nature of contract</th>
<th>Acceptable to farmers only</th>
<th>Acceptable to both</th>
<th>Acceptable to JASEC only</th>
<th>Not acceptable to both</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexible*</td>
<td>50</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rigid**</td>
<td>50</td>
<td>60</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Who should be inter-medary</th>
<th>Acceptable to farmers only</th>
<th>Acceptable to both</th>
<th>Acceptable to JASEC only</th>
<th>Not acceptable to both</th>
</tr>
</thead>
<tbody>
<tr>
<td>Each single producer</td>
<td>375</td>
<td>0</td>
<td>Agricultural extension offices</td>
<td>Producers’ association</td>
</tr>
<tr>
<td>Watershed committees</td>
<td>25</td>
<td>60</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 4. Acceptable and most preferred alternatives for farmers and JASEC (note: numbers in the bottom-right (left) of boxes represent the percentage of votes given by JASEC (farmers) to that sub-alternative).

Results from the negotiation exercise show that the characteristics of the program, as defined by stakeholders’ preferences, can serve the learning requirements for both parties and can be efficient in the provision of SRS to both hydropower and farmers. More specifically, such a program could, consistently with their preferences, concentrate in “High priority area”, promote “Technical assistance” instead of PES, use either flexible or rigid contracts and entitle
“Agricultural extension office” or the not-yet-created “Watershed committee” as intermediary between the program and the farmers. Some surprises arise from these results. Indeed, farmers show low acceptance for having the program spread all over the watershed (i.e. they suggest to concentrate in “High priority areas”) although preference for program to cover the whole watershed might be expected. Similarly, monetary incentives such as “Credit” and “De-taxation” or “Direct payment” (accepted partially only by JASEC), have, contrasting expectations, low acceptance among farmers. On the other side, farmers, consistently with their values, expressed low acceptance for selection mechanisms that promote competition among them such as “Bid through auctions”. For the component “Nature of the contract”, both parties’ acceptance of rigid and flexible contracts as alternatives to status quo (i.e. no contract) underlies a shared perception of the need to establish a formal agreement to reduce soil degradation in the watershed. While for JASEC no contract might represent uncertain investment, for farmers no contract might represent uncertain access to support. It is interesting to note that sub-alternatives supporting their direct or indirect (i.e. through their associations) involvement in negotiating support with the program received little support contrary to expected. Both JASEC and farmers acknowledged the role of agricultural extension office or watershed committee for intermediation.

Finally, after the evaluation exercise, both farmers and JASEC were asked to express their views on possible next steps in order to move forward this negotiation process. Both groups articulated the need to identify high risk areas, and better specify the nature of technical assistance sought by farmers. Moreover, both also indicated the need to create a structure for developing and implementing contracts, perhaps through a new watershed management process. Farmers also stressed the need to engage in the process other farmers within high-risk areas.
4.6 Discussion

Our paper builds on the recent paper of de Groot and Hermans (2009) whom used a stakeholders’ value-based analysis to outline potentials for PES negotiations between providers and users water-related ES. Our focus, however differ for three reasons. First, we focused our attention on the building of an institutional mechanism rather than mainly on the effectiveness and structure of direct payments to farmers. This is especially relevant when considered in the Costa Rican context where i) pioneering experience on implementation of PES schemes has put most emphasis on this compensation mechanism than on the values and interests of providers and users of ES, and ii) the location in Central America can provide insights on negotiations for ES context that might be relevant for developing countries context. Second, we put emphasis is on the provision of water-soil regulation services that provide potential for joint gains between farmers and hydropower rather than putting emphasis on the provision of services that benefit principally its user (e.g. the water board). Third, differently from de Groot and Hermans (2009) we used value-based and expert-based literature to build a negotiation template, validate and evaluate it to test our method with stakeholders’ preferences. Results from our consultations with stakeholders show that the structure of means-objectives expresses concerns for economic (i.e. transaction costs of monitoring implementation of practices, define contracts and distribute incentives) and procedural aspects (i.e. meet legal requirements in signing contracts and provide incentives) of the desirable mechanism for soil conservation. The figures and the final template evaluation in this paper provide a basis for structuring the future negotiation process.

The components and sub-alternatives reflect, beyond availability and consistency\(^\text{19}\) of resources for the program, concerns (McKenzie, 1997; Hajkowicz, 2009) on procedural aspects, such as defining strategies for distribution of resources and monitoring of program implementation, are important. Drawing alternative strategies from results of both open discussions with participants (i.e. means-end objective network) and expert-based literature allows widening “the limited and fallible perspective of a single actor by drawing on other experience and knowledge” (Smith, \(\text{As outlined in Hajkowicz (2009), many watershed conservation program have not yet adequately addressed whether investments in resources are consistent with full-range of costs and benefits of SCP providing SRS. given the focus on “hard-to-quantify and hard-to-monetize” environmental outcomes.\)
2001). For example, for the component “Nature of the contract” between providers and beneficiaries of the ES stakeholders had not mentioned important aspects of the possible contract type between the program and farmers. Bringing new knowledge in the negotiation of the mechanism, expert literature (Bougherara and Ducos, 2006) shows that the extent to which the “Flexibility” of the contract allows farmers to adapt soil conservation practices over time can be an accepted alternative to overcome status-quo, when subject to stakeholders’ evaluation.

Our strategy table, based on inputs from both consultations with participants and the literature, provides a set of alternatives under each component, some of which are acceptable or most preferred to both groups\(^\text{20}\). For example, both farmers and JASEC prefer that the program select farmers based on the principle of targeting high risk areas (steep areas with exposed slopes). This convergence of perspectives on targeting priority areas for the ES provides an opportunity for increasing efficiency in hydrological ES schemes (Goldman et al., 2007; Parkhurst and Shogren, 2007). Moreover, targeting of ES priority for watershed conservation would improve Costa Rica’s current PES program, (Wunsch et al., 2007; Pagiola, 2008).

Some procedural aspects such as “Selection of producers” have provided controversial outcomes. For example, the alternative “Auctions” that have been proposed as a strategy for conservation programs to make farmers reveal their true opportunity costs in the provision of ecosystem services (Ferraro, 2008) have received little support. As Ferraro (2008) notes, selection based on this self-revealed opportunity cost can be seen as unfair by farmers, due to incentives for competition among farmers with different resource endowment. Additionally, this sub-alternative requires the SCP to dispose of additional resources to cover the transaction costs needed to run and monitor the bidding process. For the component “Nature of support”, both groups expressed preference for “Technical assistance” rather than “Direct payments” that are being promoted by national PES programs. This preference highlights the importance of learning over time, which is highly relevant in the uncertain context in which the parties are operating. Mobilizing effective scientific knowledge and the appropriate technology (through technical assistance) can be a very effective strategy for sustainable land management (Cash et al., 2003).

This is especially the case in the context of the Birris watershed where neither the best

\(^{20}\) Some 240 strategies are possible (5x4x3x4), ignoring the potential for combining alternatives under the nature of incentives.
conservation practices to reduce soil erosion nor the potential benefits for agricultural productivity are precisely known by the parties. Moreover, this is particularly relevant considering that uncertain climate dynamics and increases in extreme precipitation events in the future might require continuous adjustments (i.e. learning over time). Farmers’ preferences suggested their concerns that “Direct payment” would involve restrictions (i.e. legal liability) on soil management. In light of the small farm-area available and the dependence on unstable market prices, farmers consistently showed preference for less-binding solutions. As shown by Zbinden and Lee (2005), the majority of participants in the currently operating Costa Rican PES are large landowners with relatively lower opportunity costs for adopting the land uses required by PES contracts. Thus, unless Birris farmers also perceive private benefits from soil conservation, the fixed payment might be perceived as too small (Pagiola, 2008) or unable to match unstable agricultural market prices during contract period. JASEC, on the other hand, viewed direct payments as acceptable, consistent with their knowledge on PES experiences (both government and user-financed PES schemes) in the country (Engel et al., 2008; Pagiola, 2008).

The relatively high degree of farmers’ acceptance of “Rigid” contracts deserves more attention, especially in the light of the agricultural production context. Based on their actual experience, farmers may have evaluated the “Nature of contract” as a way to ensure a contract-based access to “Technical assistance” but without the legal implications of receiving direct payment. Technical assistance is currently provided without a legal contract (i.e. no formal commitment) but the provision of this service is discontinuous and with a limited geographical coverage.

When asked to evaluate alternatives on the component “Who should be intermediary” between the program and farmers (e.g. including activities such as monitoring and follow-up of program activities), the former experience of participants21 might play an important role (Imperial, 1999). For example, neither of the groups have experience with the alternative “Watershed committee” (representing relevant stakeholders such as farmers) because, the committee has not yet been formed, and only JASEC has acknowledged its formation in their Birris watershed management plan. Current positive experience with the agricultural extension office might underlie the

21 Neither of the groups have experience with the alternative “Watershed committee” (representing relevant stakeholders such as farmers) because, the committee has not yet been formed, although it is included in the existing watershed management plan.
convergence of preferences of farmers and JASEC participants. The lack of support for producers’ associations by both groups might presumably be due to concerns over principal-agency issues and the lack of trust in these organizations, factors which have been also observed by a historical analysis of the farmers’ cooperative movement in the country (Anderson, 1991). The “Agricultural extension office”, highly appreciated for the technical assistance services it provides, might be perceived as a trustworthy and convenient channel for administrative tasks needed to join the program. JASEC’s lack of support for “Each single producer” as intermediators might be related to the concerns over transaction costs, indicated by experiences in other regions (Engel et al., 2008; Wunder et al., 2008). In sum, intermediary organizations, rather than direct intermediation, linking the providers and consumers of ES is seen as a desirable aspect of the program, as shown in an analysis of Voluntary Agreements in watershed protection in Costa Rica (Miranda et al, 2007). An interesting point raised by farmers was the perceived need to involve most farmers in targeted areas. Indeed, the efficacy of farmers’ soil conservation practices in providing SRS depends in part on topographical gradients and on how their actions are coordinated with upstream and downstream neighbouring producers. This territorial concern has received attention also in recent literature (Goldman et al., 2007; Parkhurst and Shogren, 2007) that discussed the potentials of appropriate targeting in ES programs using cooperative bonuses and declaration of environmental districts as a means to promote farmers cooperation in priority areas.

Finally, the identified areas of agreement can be used to create many alternative strategies that could be evaluated on the basis of stakeholders’ means-ends objectives. For example, if after further negotiation, farmers would ultimately find direct payments acceptable in place of reduced input taxes or credit, then some eight different strategies could be created from the alternatives of mutual agreement from Table 4 (1x2x2x2). These eight strategies would need to be evaluated and negotiated by both farmers and JASEC to select the best overall mechanism acceptable to both.

4.7 Conclusions

This article focused on the building of alternative strategies for a ES mechanism using decision and negotiation analysis to explore stakeholders’ values and interests. We elicited the
subjectively perceived causalities of soil erosion by applying mental model interviews, the values attached to its control and those of relevance for the design of collective response strategies by applying a value-focused approach. Stakeholders analyzed alternatives for building a mechanism, rather than relying on pre-established and fixed alternative outcomes. This approach permitted us to identify fundamental values of relevant stakeholders (i.e. providers and beneficiaries of ES) and zones of agreement that may help shape the design of more socially and environmentally efficient future programs.

While the majority of literature on PES assumes that direct monetary incentives are appropriate for fostering ES provision, this paper shows that in analyzing the complex institutional requirements of soil conservation programs, other considerations matter. Indeed, stakeholders base their preferences on issues such as fairness, trust in and experience of interaction with others, and access learning over time on the changing causes and solutions of the degradation of ES. Acknowledging these fundamental aspects in the designing of a mechanism might increase the willingness of interested parties to find agreement on SCP. This in turn could improve social efficiency and environmental efficacy of conservation programs. Further research on negotiations should include willingness among farmers to find agreements on the best mechanisms for cooperation, especially in high priority areas where returns on investments in conservation efforts promise to be greater.

4.8 References


5. Governance across-scales: regulatory mismatches and the role of boundary organizations for soil regulation-services under climate change in Costa Rica

Authors: Raffaele Vignola, Tim L. McDaniels and Roland W. Scholz.


Abstract

The degradation of ecosystem services such as soil erosion control results from complex interaction of climate extremes and soil management decisions. This complexity poses new challenges to governance systems for the definition of strategies to adapt to these changing conditions. Regulatory framework and access to information determine the capacity of actors to achieve their goals and contribute to soil erosion control. In this paper, we use the case study of Birris watershed where the degradation of Soil Regulation Services of upstream ecosystems affects both upstream farmers and downstream hydropower dams. The Birris watershed, as other parts of Central America, is characterized by high land use conflict (due to high slopes and soil-intensive agriculture) and is highly vulnerable to increasing precipitation extremes. We analyze formal regulatory framework and information-exchange networks that characterize the constellation of actors across scales that directly or indirectly influence the provision and use of these ecosystem services. Our results show that two important regulatory mismatches across scales affect the definition of societal responses at the local level (i.e. where direct actions to promote adequate provision and use of ES happen). Additionally, through analysis of information-exchange networks among actors we identify an important boundary organization such as the watershed agricultural extension office that helps diffusing information from different scales and policy areas. The formalization of the boundary role of this organization can reveal a strategic step in promoting adaptive governance. Indeed, this can improve the capacity of this organization to systematically recollect evidences of impacts on and responses to soil degradation in the area. Adaptive governance can benefit from the dissemination of this information to actors that play an important role in formulating regulations, allow and design economic incentives and implement scientific research on the degradation of soil regulation services.
Keywords: Ecosystem services, adaptation to climate change, adaptive governance, information exchange networks.

5.1 Introduction

The Millennium Ecosystem Assessment (MEA) paints a grim picture of rapid growth in demand for ecosystem services, while two thirds of ecosystems providing services (ES) are in decline (MEA, 2005). The picture is even more disturbing when the disruptive effects of climate change are considered (Fischlin et al., 2007). Coordinated adaptation efforts, within complex institutional and governance contexts and under extreme uncertainties are required if ES supplies are to better meet ES demands under the pressures of climate change (Hulme, 2005; Bodin and Crona, 2009). Yet often those relying on a specific type of ES are spatially and administratively different from those who influence the quality and quantity of that ES provision and those who generate, elaborate or disseminate information that is relevant for managing those ES. The management of Soil Regulation Services (SRS) provides a case in point. Farmers on upstream sites clearly have individual incentives to avoid erosion and retain soils on their farms, but often lack technical knowledge, equipment, capital, time or cooperation of others needed in order to change practices to reduce erosion. Downstream neighbours and more distant water users, such as hydroelectric electric facilities, bear costs that could be avoided if formal regulations would allow more resources (e.g. financial and information) to be devoted for upstream erosion control. In the parlance of economists, the potential positive externalities of SRS in avoiding siltation of reservoirs are not internalized into decisions by upstream farmers.

The effects of climate change are expected to increase the intensity of rainfall, and thus increase erosivity, with even more soil loss. In this context, actors involved in SRS management decisions need appropriate information to guide their technical, administrative and socially-sensitive actions on ecosystems. However, most governance systems for ecosystems and adaptation to climate change, however, are in their initial stages of recompiling information on impacts and analyzing feasible responses in the face of uncertainties (Eastaugh et al., 2009). In this context,

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22 These include: provisioning services such as food, water, timber, and fiber; regulating services that affect climate, floods, disease, wastes, and water quality; cultural services that provide recreational, aesthetic, and spiritual benefits; and supporting services such as soil formation, photosynthesis, and nutrient cycling (MEA, 2005, p. 9)
research is needed to improve understanding of the role of key organizations in information-sharing networks as a strategic ally for designing adaptation responses.

Information-sharing among organizations is shaped by an existing set of formal and informal institutional structures and governance arrangements that determine the capacity for collective responses to ES degradation problems (Ostrom, 2007). These include formal governance as set by laws and mandates, but also informal interactions among actors beyond their specific mandates and geographical location. This governance structure frames, oversees and implements resource management policies from broader levels of governance, such as regional or national or international, to individual land users at the local level (Adger et al., 2005).

Recent studies of governance for global environmental change have identified two crucial aspects for analysis of societal capacity to design and implement adaptation strategies. The first concerns the interaction of actors at multiple scales of governance needing different detail-levels of information on global environmental impacts (Cash and Moser, 2000). Often, mismatches or gaps arise in regulatory efforts and governance across scales, which can thwart their effectiveness. The second refers to the role of boundary organizations to serve as conduits that provide linkages (i.e. information and knowledge exchange), across scales and organizations belonging to different communities such as science, government, and civil society that makes decisions influencing ES management (Agrawala et al., 2001; Cash et al., 2003; Turton et al., 2007). To date, little research has considered both of these themes in one paper using empirical data, to see i) how quantitative network analysis can identify key boundary organizations that may help build linkages across scales, and how ii) governance systems may shape the role of and effectiveness of boundary organizations. Moreover, little empirical research has, to our knowledge, put emphasis on network governance across-scale that is relevant for the provision of ES under climate change.

The objective of this paper is to address these gaps through an empirical case regarding the provision and use of SRS in the Birris watershed of Costa Rica. Here, both farmers and a local electric company are affected correspondently on- and off-site by increasing degradation of SRS. We focus on regulatory mismatches and on the identification and analysis of the role of key actors by using policy network analysis. In the following section we address concepts and definition of governance and its relation to ecosystem management and adaptation to climate change for the case of ecosystem services. In Section 3, we describe briefly the case study
highlighting the drivers of SRS degradation and actors’ context of SRS provision and use. In Section 4, we present the methods of analysis of formal policies and mandates and, finally, the structure of policy network questionnaire and the analysis of network algorithm. In Section 5, key findings are discussed along with existing experiences and concepts for ecosystem governance and adaptation to climate change. In Section 6, we provide general recommendations for further research.

5.2 Concepts

5.2.1 Information and knowledge exchange in ES governance structures

Important components of effective ecosystem governance across scales are the exchange of information and knowledge on potential impacts and available alternatives for ES conservation (Cash and Moser, 2000; Adger et al., 2005). While information is the result of data analysis (e.g. produced to understand impacts, technical solutions, etc.), knowledge results from the interpretation and contextualization of information (i.e. requires experience and understanding of specific contexts where information is meant to be applied) (Toimu, 1999). Inter-organizational information networks, as suggested by Institutional and Organizational Learning theories, provide not only exchange of information, knowledge and awareness-raising on new issues but also have the potential to provide important information on costs and benefits of alternatives with a higher persuasiveness degree than other sources (Brass et al., 2004). This is especially important for ES contexts where a large variety of actors (who have different experiences, interests, mandates and understanding of the functioning of ecosystems, their degradation and of the possible responses; Fisher et al., 2009) interact and exchange information and knowledge in networks in order to guide their decision-making. The interchange of information and knowledge depends, among other things, on politically and economically ambiguous social networks characterizing governance of specific environmental issues (Adger, 2003; Folke et al., 2005; Pelling et al., 2005). Although debate on the definition of governance is still open (Kjær, 2004), according to Huitema et al. (2009), governance is the result of both the formally stated rules (e.g. policies, laws, etc.) and the informal interactions of actors in networks that promote collective responses to environmental degradation problems. Thus, formal mandates and interactions of diverse actors operating at different scales shape relevant opportunities and/or constraints for organizing
collective responses to natural resource degradation problems (Uitto, 1997; Koimann, 1999; Hodge, 2001). Building on these authors, governance thus comprises two inter-related aspects: 1) formal rules defined by laws and official mandates that explicitly frame actors’ legitimacy in their actions related to the environmental degradation problem at hand, and 2) informal policy structures described by interactions in networks (Piattoni, 2006) that determine their sharing of information and knowledge across scales and policy communities23 (influenced by their respective power and interests).

Emphasis on the information-sharing mechanism in this governance system is especially relevant where complexity and uncertainties characterizing a problem like ES degradation (van Noordwijk et al., 2004) require their information and knowledge to be updated to face changing conditions. In such contexts, “rigid” policies might prove inadequate24; rather the establishment of flexible rules, and production and dissemination of information to increase knowledge and learning over time may be more appropriate (Duit and Galaz, 2008). Sharing information in networks can promote common perception and understanding of the problem, and capacity to plan responses and monitor them in a wider number of organizations (Cash, 2001; van der Brugge et al., 2007; Pahl-Wostl et al., 2009).

5.2.2 Multiple scales and regulatory mismatches for SRS

Land use decisions influencing both the provision and use of ES are typically taking place inside institutional structures that span across scales (Rotmans and Rothman, 2003). For our case, the life span of downstream hydropower dams depends on the quantity of sediment transported from uplands (Southgate and Macke, 1989; Guo et al., 2000) while the impacts of erosion on farmers are valued in upstream areas (Pimentel et al., 1995). The potential joint gains among these two scales depend on whether there is coordination and information exchange among different types of actors operating at different scales and embedded in larger networks.

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23 Policy communities are defined by actors sharing experience, common specialist language. A subset of actors in larger networks so defined as “policy community” shares a common identity in terms of languages and day-to-day policy-making. For examples, scientists have limited presence in the day-to-day policy-making activities of the regulators’ communities and vice-versa (Howlett and Ramesh, 1998).

24 Rigid policies are referred to by Duit and Galaz (2008) as those that can be elaborated based on high scientific certainty and clarity on the behaviour to be (such as prohibition to smoke in public places), then clear-cut laws are effective.
Scales are thus a social construct and their definition depends on the perspective taken (Cash and Moser, 2000). Along with these authors, we understand that “scale refers to a specific geographically or temporally bounded level at which a particular phenomena is recognizable”. More specifically, erosion is recognizable at the farm level where farmers might perceive it as a problem affecting their soil fertility, at the watershed scale where downstream users might be affected by upstream activities and, finally, at the national scale where agricultural policies and scientific organizations are interested in promoting soil conservation and agricultural production potential. As we have seen, the degradation of SRS as a social-ecological problem depends on components that range from the very local level (e.g. topography and soil; farm land use decisions) to the watershed (e.g. microclimatic conditions; presence of conservation programs), to the national (e.g. distribution of precipitation; laws and incentives), and finally to the international (e.g. climate change and variability; markets; and, international agreements and funding) scale. Access to adequate resources such as information and incentives, needed to support stakeholders’ responses to ES degradation at a given scale, is conditioned by cross-scale institutional gaps and mismatches\(^{25}\) (Cash and Moser, 2000).

5.2.3 Boundary organizations for ES governance networks

Structural interactions of actors in networks has received increasing attention in social studies (Borgatti, 2009) and specifically in studies of environmental degradation problems and adaptation to climate change (Adger, 2003; Brooke, 2002; Jost and Jacob, 2004). Actors’ information exchange in networks is strategically important to effectively plan adaptive responses (Duit and Galaz, 2008). Boundary Organizations (BOs) are key actors in information-sharing networks, capable of bridging information across scales and knowledge systems. Boundary organizations provide spaces for changes in cultural aspects by facilitating mutual understanding of preferences and meanings among different epistemic communities. Indeed, they promote the creation of boundary packages, such as collaborative partnerships between farmers, scientists, and policy makers PES schemes (Guston, 2001). Additionally, BOs also

\(^{25}\) For example, the scale of information produced by an actor at national level such as a country-level climate change impact studies might require, in order to guide action on ES, downscaling of information to a specific site and communication of uncertainties to non-expert audience. Similarly, national actors such as regulators would improve their actions if building on local knowledge/experience on soil erosion (e.g. constraints and innovative solution in applying soil conservation practices).
contribute to the stability of multi-stakeholder processes (involving accountability and participation) while maintaining information-sharing mechanisms between science and policy and supporting both the building and performance of partnerships across scales (Cash 2001; Guston, 2001; Cash et al. 2003).

Structural analysis of information-sharing networks can allow identification of key bridging organizations (Burt, 2005). BOs can, thus, also be defined by structural network properties such as the number of information links across scales and different policy communities, heterogeneity of the actors connected and the decentralization level of information through its nodes (Weible, 2008). This structural definition highlights the potential role of BOs to contribute to a network’s capacity to \( i \) define what and where are the ES degradation priorities, \( ii \) which are the available solutions and, finally, \( iii \) how institutional mechanisms could be shaped to implement and monitor responses (Carlsson, 2008). Structural analytic methods use Betweenness Centrality (Freeman, 1977) as a measure of actors’ capacity to mediate and influence relations among actors (Bodin and Crona, 2009) and generate contagion of ideas (Borgatti, 2009).

5.3. Context for the Birris case study

The Birris sub-watershed, part of the upper Reventazon watershed (1500Km²), has an area of almost five thousands hectares and its population density of 161 inhabitants per square kilometre is above the national average (INEC, 2002). SRS degradation is determined by exposure to extreme precipitation, by the area’s high sloping topography and by land use conflicts. Its steep lands suffer serious soil erosion due to intensive use by horticulturalists and dairy-cattle, which comprise the major economic activity. Its vulnerability to climate change is characterized by observed increases in extreme precipitation events over the last forty years (Aguilar et al., 2005) and by the projected climate change scenarios for the region (Magrin et al., 2007). The high fragmentation of agricultural family plots and the high market orientation of its production represent a challenge for existing conservation incentive mechanisms such as PES which are challenged by high opportunity costs to local farmers (Pagiola, 2008). In this context, the downstream hydropower dams of the Administrative Board of Electric Service of Cartago (JASEC) and of the National Electric Institute (ICE) suffer the off-site effects of upland erosion. Several millions US$ are spent each year to flush and dredge sediments out of these dams. These figures
are of national interest given that (i) the Reventazon watershed is the most important in the country for hydropower production; (ii) that hydropower represents more than the eighty percent of energy source in Costa Rica; (iii) that current political goals aim at increasing use of hydropower as a national strategy (ICE, 2007).

5.4 Methods

When considering environmental governance, we focus on the analysis of formally stated objectives and mandates (e.g. as defined by national laws, decrees and official statements) and actors’ interchange of information with others. Defining management of soil regulation services in the context of watersheds requires consideration of the multiple actors from different policy communities (Van Noordwijk et al., 2007). Indeed, governance for provision of ecosystem services in agricultural landscapes can be described by the interactions of actors focusing on social and ecological systems (Hodge, 2001; Ostrom, 2007). Drawing from the pluralistic approach (Cowie, 2005) and the triologue model for water governance (Turton et al., 2007), and the specific SRS decision-making interested actors (Fisher et al., 2009), our SRS environmental policy system involves four policy communities:

1. Direct users of off-site benefits of SRS (e.g. hydropower dams downstream);
2. Direct users of on-site benefits of SRS (also influencing provision off-site) in upstream areas (i.e. farmers, their associations, civil society interested in upstream conservation);
3. Scientists providing understanding, knowledge on technical aspects of SRS provision (role of forests, soil, agriculture and climate on soil erosion) and those involved in dissemination of science; and,
4. Regulators providing policy guidelines relevant for the management of watershed and their SRS.

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26 Cowie (2007) indicate the potential stakeholders to be involved in the design of collective actions for watershed management planning such as rules-makers (e.g. government agencies), actors directly involved in benefits and/or costs of decisions (i.e. providers and users of SRS) and parties with technical knowledge (e.g. scientists and technical agencies).

27 These authors identify government (rule makers), scientists and civil society (actors directly and indirectly affected by ES management decisions) as three important pillars of water governance.
Defining the network boundary represents the first step in the application of social network methods (Knoke, 1990; Wasserman and Faust, 1994). We identified actors by means of a two-step complementary procedure, consulting key documents and informants (Jost, 2004). First, we identified laws and official mandates relevant for each policy community (Penker and Wytrzens, 2008). Where organizations were explicitly mentioned in the laws, they were included in the list of actors. Secondly, we complemented this initial list using reputational snowball techniques (Farquharson, 2005) asking key informants who represented each of our four policy communities at different scales to list organizations that they considered to be influential in issues such as soil conservation, climate studies, land planning, watershed conservation, and hydropower production. Then, we explicitly defined those organizations (associations, ministries, private companies and NGOs) that actively contribute to setting political agendas, activities, and proposals, or that participate in the implementation of policies and actions in one of those areas relevant for SRS provision and use. Because individual respondents at one scale within an organization may not acknowledge all interactions of all departments of his organization, (Brinkerhoff 1996), we consider sub-units of such organizations (e.g. departments) as actors themselves. Thus, we identified the actors/organizations concerned with formulation, advocacy and selection of alternatives to respond to SRS degradation problems (Knoke, 1990). For the analysis of formal mandates and objectives, for each identified organization we reviewed published documents and characterized their relevant tasks for designing and implementing actions to improve SRS. During the network questionnaire meetings we asked open-ended questions to interviewees on what aspects they perceived as a barrier or as an opportunity for improving their support to SRS provision (McDaniels et al., 2006). These interviews were transcribed and used to cross-check and complement our secondary data on laws and official mandates to analyse formal policy context.

5.4.2 Network analysis

Reflecting the work of Borgatti (2009), we have considered four basic aspects key to analyzing multi-actor interactions using social network theory: theoretical framework, research question, relations and structure. Our theoretical framework rests on theories such as Institutional Theory (DiMaggio and Powell, 1983), Organizational Learning Theory (Levitt & March, 1988) and theory of Adaptive Governance (Duit and Galaz, 2008) all of which emphasize the role of information
transmission among actors’ networks to promote learning and design of collective responses (see Section 2). Our research question aims to identify key bridging organizations in order to subsequently contrast their boundary positions with evidence on their current and potential ability to contribute to networks’ adaptive capacity. Relations refer to the content of the connection among couples of actors. In our case, this would include information or resource flows connecting two or more actors for its relevance to learning (Duit and Galaz, 2008). The concept of structure refers to the position of ‘nodes’ (i.e. organizations) with respect to other actors when a given relation is considered. We employ a widely used concept to study structural position in networks: ‘betweenness centrality’ (BC) (Freeman, 1977), which measures the bridging capacity of an actor to connect other pairs of actors.

5.4.2.1 Building the questionnaire for network analysis

We analysed three types of relations based on previous research (Knoke, 1990; Cash et al., 2003; Raab and Kenis, 2006):

1) **Position** in inter-organizational information-flow networks as a proxy of their bridging functions between local watershed level and national policy and science-making; this is calculated by an analysis of a policy network matrix (see below);

2) **Perceived influence** as a proxy of the persuasive power of an actor given by how he is perceived by others;

3) **Perceived competence** as a proxy of the perceived credibility of information produced by an actor by other actors which can influence how effective is this information in promoting responses.

Building on Knoke (1990) and Weible and Sabatier (2005), we presented a list of organizations to every respondent and asked them to use the corresponding scales to indicate how they relate to other organizations, namely:

1) Please check the corresponding box for those organizations from which you receive information useful for your duties and functions in your own organization (i.e. binary variable)

2) Please check the corresponding box for those organizations to which you give information produced by your own organization (i.e. binary variable)
3) On a scale from one to four please rate how influential you perceive each of the organizations in the list (where no check is no opinion, 1 is very low influence and 4 is the highest perceived influence).

4) On a scale from one to four please rate how competent you perceive each of the organizations in the list is (where no check is no opinion, 1 is very low competence and 4 is the highest perceived competence).

5.4.2.2 Matrix analysis of network data

Network data recompilation was used to create symmetrical matrices (i.e. adjacency matrix) with nodes (i.e. organizations) in the first columns and in the top row, filled with the values assigned by each respondent (on the row) about his relation to the others (i.e. listed in the top of each column) (Hannemann and Riddle, 2005). For our study, each relation was analyzed through its specific matrix, although combinations of relations can be visualized in a single graph. To run analysis of the matrices we used UCINET (Borgatti and Everett, 2002). To visualize results we used its complementary software NetDraw which allows representation of nodes, relation, and network parameters (Brandes et al., 1999). Several algorithms for network analysis are available in the UCINET-NetDraw package. For our information network, we analyzed parameters largely used in policy network analysis (Knoke, 1990). We first confirmed information flows by checking whether stated “give to” information flow is confirmed by the receiver.

Then, we used network algorithms for structural analysis of overall network characteristics such as density (defined by the total number of existing ties out of all possible ties) and actors’ Betweenness Centrality (BC). Density, defined as a measure of group cohesion, takes a value between 0 (no ties) and 1 (all actors inter-linked to each other) is the average of the standardized actor degree index as well as a fraction of the network ties for a given relation (Wasserman and Faust, 1994:181). Betweeness Centrality (BC) measures the bridging position of an actor and is determined by an actor’s position with respect to two others (i.e. the minimum required for defining bridging positions) (Knoke, 1990; Brandes et al., 2003). This position measure of an actor is formally defined by Wasserman and Faust (1994:190) as:

$$C_B(n_i) = \sum_{j,k} g_{jk}(n_i) g_{jk}$$
Where \( C_B(n_i) \) is the *Betweenness Centrality* of actor \( i \), \( g_{jk} \) represents the number of geodesics linking actor \( j \) with actor \( k \). Then \( g_{jk}(n_i) \) is the number of geodesics between these two actors that passes through actor \( i \). This algorithm assumes that links (i.e. information paths) have equal weight (i.e. probability to be chosen), and that communications will travel along the shortest route (regardless of the actors along the route). This index is then a sum of probabilities with a minimum of 0 (if the actor falls on no geodesics) and maximum given by the number of pairs of actors not including \( n_i \) reached when \( i \) falls on all geodesics. Finally, we analyse the average values of perceived influence \((P_i)\) and perceived competence \((P_C)\) that are attributed to each actor by the others in the network.
5.6 Results

5.6.1 Network boundary, formal policies and mandates of organizations across scales

Based on key informants, analysis of policy documents and face-to-face interviews we identified the boundary of the network (i.e. the constellation of actors) (Table 1).

Table 1: Actors and their scale scope defined by the network boundary for improving SRS in Birris watershed (in Appendix 1 see extended version of organizations’ acronyms, formal mandates).

<table>
<thead>
<tr>
<th>Scale</th>
<th>Policy area</th>
<th>Demand</th>
<th>Supply</th>
<th>Science</th>
</tr>
</thead>
<tbody>
<tr>
<td>International to national</td>
<td>Regulation</td>
<td></td>
<td>CRRH, IICA, IUCN</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Demand</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>National</td>
<td>Supply</td>
<td>CRRH, IICA, IUCN</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Science</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>National to local</td>
<td>Regulation</td>
<td>ARESEP, Agua-MINAE, FONAFIFO, CIA</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Demand</td>
<td>ICE, ICE-UMCRE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regional</td>
<td>Supply</td>
<td>IDA, CNP, IMAS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local</td>
<td>Science</td>
<td>CNE</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Policy area</td>
<td>JASEC</td>
<td>COMCURE</td>
<td>ASA-Pacaya</td>
</tr>
</tbody>
</table>

1 Extended organizations’ names are in Annex 1.

At the national scale, actors such as IICA and CRRH disseminate information on climate or agriculture-related agreements28 that influence benefits and costs of policies dealing with ES-related land uses in the country by providing inputs to design laws, research programs and mechanisms to promote SRS conservation. Similarly, large civil society organizations such as IUCN organize and participate in national and international initiatives to raise awareness on climate change and the role of ecosystems in adaptation policies. We also find organizations regulating and providing incentives for water resources and watershed management in general such as

28 United Nation Framework Convention on Climate Change or the US-Central America Agreement on Free Trade (CAFTA; with a strong agricultural component).
For example, these types of organizations establish rules that affect the economic efficiency of SRS provision to hydropower production. In the science policy area we have organizations dedicated to production of scientific studies on climate change, its expected and observed impacts and on best practices for SRS such as IMN, CIA-UCR, CADETI and INTA-MAG. Scientific information is mainstreamed in national policies through governmental initiatives such as IPN and ENCC also promoting strategic partnerships to initiate actions on mitigation and adaptation. Other organizations use scientific information to define priority areas and regulate how land use management and change should comply with technical standards to promote SRS provision such as CNE, MAG and SENARA. We also find government agencies that support programs to improve farmers’ well-being and reduce their vulnerability to markets and to climate extremes through training, dissemination of technical information and by promoting partnerships of farmers’ associations thus improving their land management practices such as IMAS, CNP and IDA. On the demand side of SRS, hydropower company ICE has interests and promotes watershed management in its priority watersheds such as Reventazon thus promoting partnerships with other actors also interested in controlling erosion.

At the regional watershed scale, intermediation between national directives and local implementation is key to provision feed-back information in both directions. For example, national political directives strive to empower watershed committees such COMCURE to establish participatory and decentralized actions to conserve priority catchments also in partnership with another hydropower company demanding SRS as JASEC. At a more local scale, under the recent decentralization efforts of the national government, the local municipality (MUNI) is mandated to regulate land management. In upstream locations, farmers associations, representing small to medium producers (ADICO, ADAPEX and COOPEBAIRES), share common goals of promoting productive capacities and marketing of agricultural products as well as information exchange on alternative technologies relevant for SRS.

5.6.2 Structural analysis of the governance network

The network representation in Figure 1 highlights some important actors as to their information-bridging potential. Values in Table 2 give more quantitative information on the network values associated with each actor. Considering that density of ties equal to one represents full connections of all nodes, the overall density of our network is low ($D = 0.12$) with only 214 ties
present (i.e. out of 1722 possible ties). Our results from the analysis of $BC$ highlight key nodes that bridge information across scales and policy areas\textsuperscript{29}. Although there is a relative continuum in the range of values ($BC_{\text{max}} = 52.16; BC_{\text{min}} = 0.62$), the first five organizations\textsuperscript{30} (IMN ethnic unit, ICE environment, CNE, ASA-Pacaya and regional SINAC) in Table 2 show high $BC$ values highlighting their bridging role for information exchange across scales and policy areas.

Figure 1: Structure of the information network showing the actors (node) in quadrants by scale (x) and policy areas (y), the confirmed information flows (arrowed links) and its Betweenness Centrality (size).

\textsuperscript{29} We tried an analysis of only reciprocal ties where actor $x$ and $y$ interchange information in both direction as tried by Hanneman RA, Riddle M. (2005). (Hanneman, R., R.A., Riddle, M., 2005. Introduction to social network methods. Riverside, California , available at: http://faculty.ucr.edu/hanneman/) When running this analysis, IDA-regional is the most central actor of the whole network and the rest of organizations’ centralities are more evenly distributed. However, from this point on, we will discuss the results of our confirmed “give information to” matrix that allows identification of different high-$Bc$ values in the information flow mechanism at different scales.

\textsuperscript{30} Considering the continuum of values, in correspondence of the fifth organization there is the highest value-jump/discontinuity (i.e. 6 points) to the sixth.
The vector measuring *perceived influence* \( (P_i_{\text{max}} = 3.6; P_i_{\text{min}} = 1.6; P_i_{\text{average}} = 2.9; P_i_{\text{median}} = 3.1) \) correlates with the vector measuring *Betweenness centrality* \( (R_{\text{Pearson}} = 0.407; p < 0.05) \) suggesting that bridging positions in the network are associated to persuasive power. On the other side, *Perceived Competence* \( (P_c_{\text{Mean}} = 2.6; P_c_{\text{S.D.}} = 0.3; P_c_{\text{Median}} = 2.7) \) is not correlated to values of *Betweenness Centrality* but is significantly and positively correlated to *Perceived Influence* \( (R_{\text{Pearson}} = 0.54; p < 0.0001) \) (Table 2).
At the local level, actors such as private providers of agricultural inputs and farmers’ associations (COOPEBAIRES, ADICO, ADAPEX) show very small BC values. Their main information sources are agencies promoting farmers’ productive activities (ASA-Pacaya, regional CNP and MAG, and CNE).
Watershed level is a scale where organizations can be important to information exchange from local to national scales and across different policy areas. Departments of JASEC and ICE, exchange information among themselves and with other organizations at the regional level that focus on SRS science research and dissemination, such as INTA-Planton, MAG-regional and ASA-Pacaya, all of whom show high BC and a perceived competence and influence value ($P_c = 2.8$; $P_i = 3.3$). These values are among the highest in the network (i.e. in the percentile 75). COMCURE shows a low BC value. At the national scale, the largest Betweeness Centrality value of the IMN -technical department is consistent with its mandate to provide information on climate change to a wide range of actors in different policy areas (e.g. technical information on extreme events that might affect hydropower production and/or agricultural producers). Moreover, in line with its mandate to coordinate the National Communication to UNFCCC on both mitigation and adaptation, IMN recompiles information from many sectors to synthesize priorities of different sectors. CNE, as a national organization with local branches (e.g. community emergency committees), bridges information among users of SRS at national and watershed level (e.g. ICE-Pisa and JASEC correspondently), scientific organizations (i.e. national INTA researching on soil conservation alternatives) and local committees dealing with landscape management. Regulatory agencies such as MAG, MINAE, SENARA and institutionalized multi-stakeholder committees such as ENCC, IPN, and CADETI have relatively medium to low BC values possibly due to their recent formation and/or marginal role in information sharing mechanisms. Finally, actors at the international-national interface such as IICA, CRRH and IUCN show low values possibly due to the focus of our local case study31.

5.7 Discussion

Our results show that beyond the institutional and formal policy framework, organizations interact and support initiatives across scales, building informal partnerships and linkages to cope with their SRS degradation problems. Our formal analysis of networks has shown that there are key nodes/organizations that help provide information across scales and policy areas and whose important role should be re-evaluated by national policies.

31 We could have expanded the boundary of the network to the international arena but potentially could have lost relevant details on the national networks that influence policy-making for our local case study.
Some authors in recent articles have outlined the role of national policies to provide an enabling institutional environment and appropriate resources for cross-scale governance of environmental degradation problems (Adger et al., 2005; Duit and Galaz, 2008). The intended goal of the Costa Rican national policy on soil resources (Law 7779) is to “protect, conserve and improve soil resources in an integrated and sustainable management of other natural resources and by promoting adequate environmental planning”, identifying the Ministry of Agriculture (MAG) as the implementing agency. The law sets the framework to provide incentives, technical assistance, and formation of management committees to foster soil and water conservation. More than hundred laws in the country deal with water-related issues, hindering the identification of clear administrative responsibilities for protecting water related ecosystem services such as SRS (Segura, 2004; Miranda et al., 2006). In spite of this institutional context, our results show that several actors, following their mandates and/or interests have promoted collaborative efforts to build capacity, knowledge and actions (Miranda et al., 2006) at different scales.

For example, IMN along with regional and global interests (PACADIRH and GEF), has implemented projects on adaptation to climate change in areas characterized by vulnerable water resources which have involved many national (including ICE and MINAE) and local organizations. These results support findings by previous research on inter-organization networks for biodiversity conservation and adaptation to climate change (Brooke, 2002). National organizations such as CNE, IMN, MINAE have conformed to the recommendations of the National Consultative Commission for Climate Change (2003) to promote adaptation responses in the country. Similarly, MINAE together with MAG and CADETI have been promoting, since 2004, an initiative to prevent land degradation through collaboration with civil society, and local initiatives for land planning and economic development.

At the local level, farmers, affected by on-site effects of SRS degradation in upstream areas search for information on technological alternatives through their networks of private agencies dealing with agricultural inputs and/or through institutional channels of government extension offices such as ASA-Pacaya or MAG. These organizations transfer technical/scientific knowledge on soil conservation alternatives produced by national research organizations such as INTA and

32 In the case of private extension services dealing with agricultural inputs there might be a conflict of interests for the bias towards marketing of their own products to farmers which not necessarily are environmentally friendly.
CIA-UCR. Similarly, actors affected by the off-site effects of SRS degradation such as JASEC and ICE are involved in initiatives to cope with SRS degradation. These types of actors implement both private corporate responses (Smit et al., 2000) and use institutionalized structures to build alliances for planning and implementing adaptation responses. For example, JASEC and ICE, directly bearing the costs of sediments removal from their reservoirs, have adopted corporate restructuring of departments reflecting the need to respond to SRS degradation costs. The JASEC management board has adopted a formal resolution to institutionalize a watershed management unit to channel its resources to concrete conservation actions. Similarly, ICE has placed its formerly separate watershed management unit\textsuperscript{33} ICE-UMCRE under the production units to monitor and cost watershed conservation actions against evidence of benefits in reduction of operation costs (i.e. sediment removal). As part of these responses, these organizations promoted collaborations with the ASA-Pacaya extension office to support dissemination of innovative soil conservation practices.

The capacity of this cross-scale governance system to respond to SRS degradation is influenced by distribution and access to funding (e.g. to sustain monitoring and learning mechanisms across scales; Brooke, 2002) and information (e.g. on alternatives to respond to changing conditions). Distribution and access to these resources is influenced by institutional mismatches (Cash and Moser, 2000). Two examples will help highlighting how institutional mismatches and information gaps can hinder actors’ capacity to cope with ES degradation problem. We then show, through structural analysis of information-sharing network, that BO can be an important governance asset to help overcoming these gaps and mismatches.

The first example refers to access to funding for watershed conservation initiatives. ARESEP, the regulator of tariffs for public services, requires sound technical evidence for assigning rights to access financial incentives to hydropower investing in watershed conservation. In other words, the hydropower facility must provide sound scientific evidence approved by MINAE, that the investments in watershed conservation activities are necessary for the sustainable provision of electric service\textsuperscript{34}. The large uncertainties characterizing SRS provision under climate change

\textsuperscript{33} This unit focused on broad integrated watershed management activities not specifically tight to production of hydropower.

\textsuperscript{34} In this way, the marginal investments made to promote water-related ecosystem services such as SRS in the watersheds can be considered as corresponding to the marginal cost of producing the service and as such can be detracted from the tax amount due.
represent a serious challenge. In this respect, ICE is autonomously promoting the installation of monitoring stations to measure sediments from priority watersheds where conservation activities are currently being supported (i.e. to increase evidence-based inclusion of SRS conservation costs in electric tariffs). Generating information on soil conservation activities and its effects requires ICE to collaborate and exchange information over time with local partners who intermediate with farmers.

A second example of scale mismatch is of “assessment and management” type (Cash and Moser, 2000) and is related to the contrast between the activities, defined by national actors, to be funded for watershed protection (based on the FONAFIFO list of eligible activities) and the realities of land uses in watersheds where JASEC and ICE are operating that require updating of information. Eligible activities under the FONAFIFO scheme include only tree-based land uses as a way to protect the provision of water services, used for the calculation of the environmental tariff (to internalize the SRS conservation costs; Ponce, 2006) and is based on uncertain scientific evidence (Locatelli and Vignola, 2009). Moreover, emphasis on trees excludes priority areas of watersheds such as Birris. Here, providing support to technical information agencies (e.g. improving soil conservation practices) would be a more acceptable alternative to current PES incentives (Vignola et al., 2009) which cannot compensate for the large opportunity costs faced by small-holders horticulturalists.

These mismatches suggest that policy objectives to achieve sustainable provision of services are challenged by inherent uncertainties in estimating costs and benefits of SRS conservation responses. In this context, information-sharing mechanisms can improve capacity of institutions to target investments (i.e. where and what actions) and monitor their effects over time. Our structural analysis highlights that some key organizations at the national level such as IMN and CNE operate within networks for coping with climate change vulnerability and biodiversity conservation issues in Costa Rica (Brooke, 2002). Although, SINAC, UCR, MAG and other organizations appear at the top of the list, the high BC values of the agricultural extension office ASA-Pacaya deserve discussion. ASA-Pacaya has enabled connections between local direct SRS stakeholders (e.g. providers and users) to others across scales and policy communities. It is crucial to note that at the intermediate scale of the watershed, bridging positions are especially important. While national policies have designed institutional spaces such as COMCURE to
mediate across scales and sectors, the role of a decentralized watershed management institution in information sharing is not yet fully acknowledged by other organizations in the network\footnote{As shown by the low citation in information exchange by other actors.} (possibly due to limited experience and resource endowment; Diaz et al., 2009). Watershed soil conservation initiatives currently in place, however, suggest that other mediators are facilitating relevant partnerships. The bridging position of ASA-Pacaya, the only non-national organization among the top five $BC$ values, results from its involvement in interchange of information across scales and sectors (such as those for SRS conservation). ASA-Pacaya is involved in SRS initiatives with actors from different knowledge areas of SRS policy such as JASEC, ICE, INTA and CIA-UCR reflecting its boundary role. Indeed, this result supports the findings of Cash (2001), which outlined the key role of agricultural extension organizations as boundary organizations spanning knowledge systems and of Mahanty (2002) who showed that intermediary positions (between the state and villagers in India) are crucial in facilitating conservation interventions for building trust and the design of legitimate solutions.

Multiple knowledge systems are required to address the complexities and uncertainties associated with estimating climate change impacts on watershed SRS and the design of responses (Cash et al., 2003; Hulme, 2005; Pelling et al., 2005; Duit and Galaz, 2008). The high $BC$ values of ASA-Pacaya reveal its knowledge-sharing potential\footnote{A similar use of $BC$ can be found in the analysis of Leydesdorff (2007) on the knowledge-sharing potential of scientific journals where high $BC$ values indicated journals with “strong trandisciplinary contents” (i.e. able to transmit, translate knowledge from different academic fields).}. ASA-Pacaya plays an important boundary role while \textit{i}) communicating research across scales, \textit{ii}) translating messages into appropriate languages for different systems of knowledge (i.e. policy areas or communities of practice) and \textit{iii}) mediating among the different interests characterizing them. To enhance this role, boundary objects (e.g. reports, forecasts, models) produced by boundary organizations should be accountable to both science and policy communities and through different scales of organizations (Tuinstra et al., 1999; Guston, 2001). An example from our research might help highlight this role. ICE needs information on climate extremes events provided by IMN and on the effect of conservation practices in place in the watershed on erosion provided by INTA or CIA-UCR. These actors promote and implement soil conservation research projects in collaboration with ASA-Pacaya that directly works with farmers. The activities of ASA-Pacaya include the provision of...
technical information on soil conservation alternatives to local farmers, support of national and international research initiatives (e.g. INTA-INIA’s Plantron Pacaya soil conservation project; or IUCN-CATIE project\textsuperscript{37}) focusing on soil erosion control and climate change impacts. The results of such research are presented in national fora and disseminated to relevant national committees. Similar to the case outlined by Cash (2001), \textit{ASA-Pacaya} supports efforts to define water and soil management as a multilevel problem connecting national academic research, watershed committees, providers (i.e. the farmers) and users of SRS such as \textit{ICE} and \textit{JASEC}.

This boundary organization not only transfers information down to farmers, it also feedbacks information ‘upwards’. More specifically, \textit{ASA-Pacaya}, due to its local presence and support to farmers’ decisions on soil management, feeds information back to scientists and policy-makers supporting 1) identification of new research needs and 2) data recompilation on impacts of climate extremes on SRS needed to reduce uncertainties in global change impact studies (Ayensu et al., 1999). Finally, experience in the US proves that stability and resource endowment for local technical assistance services are keys to support the monitoring of complex ecosystem degradation problems, and to identify key research areas with local stakeholders especially under climate change (Joyce et al., 2003). These authors stress the need to institutionalize these types of services to improve the adaptive capacity of society. Nevertheless, institutionalization might be hindered by actual resource endowment, a result of past policy decisions. Indeed, as outlined by Eakin and Lemos (2006), the capacity to provide adaptive responses to environmental degradation problem of Latin American States (e.g. to provide stable support for the boundary work of agricultural extension offices) has been reduced by past decisions. In our case, the actual resource endowment of ASA-Pacaya results from decisions to reduce public expenditure taken under the implementation of Structural Adjustment programs back in the 1980s (Leclerc and Hall, 2007). A limitation of our approach was determined by the static perspective we have on information-sharing network. Indeed, SRS provision and use happens in local contexts and over time. Moreover, actors involved in information-sharing networks modify their understanding and interests, and shape their preferences on alternative actions over time. Further research would consider analyzing the historical evolution of ideas, actions and policy issues raised over time as a consequence of network interchange of information in Costa Rica.

\textsuperscript{37} This project analysed future potential land use scenarios and their effects on on-site and off-site effects on SRS provision.
5.8 Conclusions

We addressed two important aspects of governance system for ecosystem services under climate change, namely: institutional mismatches and the role of boundary organizations. We analysed across scales through an empirical study, formal regulations and mandates that frame actions of relevant actors to design responses to SRS degradation and inter-organization information-sharing networks. We identified important regulatory mismatches affecting access to scarce financial resources. We also identified, through policy network analysis, important boundary organizations that have potential to foster adaptive responses in governance networks. However, past decisions have weakened the operational capacity of this boundary organization. Our study suggests that institutional efforts to strengthen the boundary role played by the extension office could benefit continuous learning which is a prerequisite of adaptive governance. Further research might shed light on i) how the information timeliness and resolution scales by different actors provides sufficient for organizations’ decision-making processes, and ii) how networks evolve over time and under different policy constraints and opportunities.

5.9 References


Leydesdorff, L., 2007. Betweenness centrality as an indicator of the interdisciplinarity of scientific journals 58(9), 1303-1319.


Tuinstra, W., Hordijk, L., Kroeze, C., Moving boundaries in transboundary air pollution co-production of science and policy under the convention on long range transboundary air pollution. Global Environmental Change 16(4), 349-363.


6. Conclusions

6.1 Research questions and their rationales

This section describes and summarizes the framework and scope of the questions addressed in this thesis. The thesis investigates human-environment system dimensions of soil erosion and its control in Costa Rica. The analysis of the human system relevant for soil erosion control requires the consideration of the decision making and interactions of actors operating at different scales. This is mainly due to how their decisions influence the specific dynamics of soil erosion that starts in upstream areas where topsoil particles are detached and, through water runoff transportation processes, flows down to downstream areas. Societal responses have been based on assumptions on actors’ decisions and interactions along these environmental processes. Society has historically assumed an inverse relationship between forest cover in watershed and water-runoff and this has driven most efforts to protect water resources and watersheds in general. However, systematizing peer-review studies worldwide reveals that these decisions might be based on uncertain assumptions on the relationship among upstream forest-cover effects on water-related ecosystem services such as control of runoff (and thus laminar erosion processes).

On the other side, in Costa Rica societal collective responses, characterizing the human component of the system, have assumed that actors directly benefiting from on-site and off-site SRS such as upstream farmers and downstream hydropower facility respond mainly to economic incentives structures. The motivations of these two types of actors to get involved in SRS management depend on how the degradation of SRS affects their activities. More specifically, for upstream farmers soil erosion is a concern due to its effects on decreasing soil fertility and increasing the need to restore the soil nutrients lost. On the other side, hydropower facilities are concerned by the increasing costs of managing sediments coming from upstream areas to their dams. However, the decisions of these actors are driven by their cognitive and socioeconomic characteristics and by institutional settings in which they are embedded. Indeed, incentive distribution mechanisms as well as general institutional settings have important consequences on the constraints and opportunities faced by these actors in promoting soil conservation. This thesis has addressed questions arising from these societal assumptions by analyzing the human
and the environment systems of soil erosion and its control in the specific case study of the Birris watershed of Costa Rica.

**Chapter 2** concentrates on the questions related to the environmental consequences of upstream forest-cover change on watershed hydrological responses including water runoff control (an important driver of topsoil erosion and downstream siltation. First the environmental characteristics of the relationship among upstream land uses and downstream hydrological effects including water runoff, base flows and the regulation of water cycle was analyzed. Then, in an aggregated meta-analysis evidences from worldwide watershed experiments on how upstream complex land-use mosaics influence hydrological responses influencing water runoff and consequently top-soil erosion were analyzed.

In the following chapters, questions of the thesis focus on the constraints and opportunities for the human system to organize collective responses to promote upstream soil conservation measures (i.e. thus reducing water runoff and its consequences on downstream users of soil regulation services). Research questions and focus follows the multiple scales at which specific decision-making processes are required.

So, the questions of relevance for **Chapter 3** focus on decision-making of local upstream farmers. Their decisions on soil management directly interact with a climatic (i.e. precipitation intensity) and site-specific (i.e. topography and soil types) to determine the level of provision of soil regulation services to downstream area. The specific questions refer to how territorial, cognitive and socioeconomic aspects combine to characterize different voluntary efforts by farmers to control soil erosion. This addresses the hypothesis that mainly socioeconomic aspects determine the level of conservation efforts implemented by farmers while cognitive aspects (such as risk perceptions of erosion, values and knowledge on causes, effects and solutions) do not.

Moving at scale of the whole watershed, the analysis of decision-making processes need including the analysis of decision-making and interaction (along the specific processes of upstream topsoil loss and downstream transportation of sediments) of those directly involved with the on-site and off-site effects of SRS degradation. In **Chapter 4**, the question on what institutional characteristics should a collective response among these actors have is analyzed. Although multiple objectives characterize the definition of common responses among these
actors, society has been driven by assumptions on the role of direct economic incentives (e.g. Payment for Ecosystem Services) to promote socially desired mechanisms. The question addressed in this chapter refers to what other objectives, in addition to direct payment-transfer, compose a socially desired mechanism and how negotiation analysis can help structuring collective responses accounting for those objectives.

Decisions of actors directly involved with on-site and off-site consequences of SRS degradation are constrained and fostered by their access to proper regulation framework and information. In this respect, decision-making of different actors (i.e. other than those directly involved with SRS provision) has direct or indirect influence on collective actions to reduce SRS degradation. Indeed, this direct and indirect influence happens in a complexity of contrasting objectives, different knowledge systems and different information-needs and -exchanges among actors. In this complex multi-actors’ setting, research questions for Chapter 5 refer to i) which institutional mismatches and gaps condition decisions of those directly involved in SRS provision and benefits and ii) which actors play an important boundary role across scales and knowledge systems providing space to address those mismatches and gaps.

Finally, in the Annex 2, I do not address a specific research question but present the results of a consultation involving more than 80 stakeholders from Latin America involved in research and policies on ecosystem services and adaptation to climate change. This consultation shows an interesting match among findings of the thesis and stakeholders’ concerns on the role of different actors (i.e. directly or indirectly involved with provision and use of ecosystem services under climate change).

6.2 Unanswered research questions, limitations and future research

The high complexity of the human-environment system characterizing SRS on- and off-site provision challenges transdisciplinary research and leaves space to many un-answered questions. We here highlight the most important aspects that could not be addressed in this thesis and that can be object of future research efforts. Starting with the analysis of the environment component, we could not include, in our meta-analysis, paired-catchment experiments considering comparison of runoff responses of agricultural watersheds with different efforts of soil management in production units. Increasing evidences from around the world in this respect
could improve also informed targeting of soil conservation policies in areas of priority watersheds in developing nations. Moreover, our meta-analysis could not benefit of comparison of forest cover effect in watersheds with different level of soil degradation as a way to demonstrate the beneficial role of forest in other regulation services associated, for example, to water infiltration. The following three papers on the human component, we also outline some un-answered research questions on the factors that hinder or promote how individuals’ or collective’s responses to SRS degradation are designed and implemented.

At the individual farmer level, our analysis has identified, based on combination of cognitive and socioeconomic variables, groupings of farmers according to their conservation efforts. The model used expanded the traditional econometric analysis of soil conservation adoption decisions by adding risk perception and knowledge. However, for future research analysis of farmers internal network for information-sharing might reveal interesting processes of information dissemination that complement and update their knowledge so as their perception of the risk factors affecting SRS degradation.

At the watershed scale level the two-parties negotiation analysis is only partially covering the issues that must be taken into account SRS management. Indeed, spatial aspects are particularly relevant in defining strategies to promote collective actions especially regarding the provision of off-site benefits to downstream actors. Here, more research is required on what strategy is socially acceptable in a given context to promote collaboration of farmers by erosion risk priority areas. More specifically, soil management decisions of farmers in upper stream areas determine the efficacy of soil management practices in lower stream zones. In this respect, future research might be interested in looking at the most-preferred incentives mechanisms to promote negotiations/cooperation among farmers according to their relative spatial importance of their soil management decisions. In the analysis of cross-scale information network interactions future research in the benefit of adaptation planning could analyse the stability of networks under different sectorial policies that affect objectives and interests of actors to interact and share information. Considering that the role of extension offices is strategic in adaptive governance of SRS, a thorough analysis of incurred costs and expected benefits of investing in these services in the face of climate change projected increase in erosive extreme precipitation events might
promote revision of past decisions that reduced their available resources and could be part of an analysis of the benefits of SRS protection in adaptation planning in Costa Rica.

6.3 Main findings

In the environment system analysis we could show that, systematizing different studies comparing the effect of natural forest cover and plantations (NFCP) vs. non-forest cover (Non-FC), there is no significant difference in the contribution of these two groups of land uses in controlling storm flow (Sections 2.3.2 and 2.3.3). Since this hydrological response is a strong proxy of water runoff and thus soil erosion results indicate that improved soil-management also in lands with low or no forest-cover (such as agricultural and livestock productive units with soil and water conservation practices) can also contribute to controlling soil erosion.

In upstream locations, traditional socioeconomic variables are only partially influencing farmers’ decision making on soil conservation. Consistently with previous literature, our findings (Section 3.4.4) farm size can be an important determinant of soil conservation behaviour. Results show that this is especially true in the case of small farmers where, although showing higher perception of erosion risk, farm land has a high opportunity costs and the benefits of soil conservation practices might be perceived too little. In addition to traditional socioeconomic variables, our decision model indicates that farmers’ awareness of soil conservation causes and impacts is also a prerequisite of soil conservation behaviour although not sufficient. Indeed, the location of producers in high erosion areas and in areas covered by soil conservation program is a strong determinant of soil conservation behaviour. Similarly, higher risk perceptions on the role of human activities and negative values on the extent to which technology can help overcome consequences of topsoil loss are importantly associated to higher farmers’ soil conservation efforts in upstream areas. Thus, expanding access to programs raising awareness on the consequences of human activities and limitations of technologies in addressing the effects of soil erosion can prove a highly cost-effective strategy to increase SRS provision both on-site and off-site.

At the watershed scale, applying negotiation analysis methods helped outlining and structuring the multiple objectives characterizing parties directly involved with SRS on-site and off-site provision. We could synthesize and present formally and jointly preferences of SRS directly-
related actors over the characteristics of a soil conservation mechanism. Our results show that key governance aspects such as types of incentives, fairness in distribution of incentives, and trust in intermediary are essential component to design socially-desired mechanisms (Sections 4.5.1.1 and 4.5.1.2). Direct payments for ecosystem services (highly promoted in national watershed conservation programs) appear as one of the least preferred incentive type. Instead, technical assistance is seen as an appropriate way to maintain productive activities while protecting SRS. Intermediary actors are needed to mediate (i.e. to reduce transaction costs) among the incentive-givers and their intended beneficiaries that are supposed to implement soil conservation.

The analysis of formal policies and mandates (Section 5.6.1) that across scales constrain or promote actors’ responses to SRS degradation highlighted that institutional mismatches hinder the possibility of farmers and hydropower to access additional resources to promote their collaborative efforts. In this respect, formal laws require users of off-site SRS such as hydropower companies to demonstrate the real costs and benefits incurred by activities to protect their priority watersheds as a prerequisite for including an environmental tariff in the electric bill. However, data scarcity and deep uncertainty characterize such studies especially in the context of climate change impacts on soils in the future and possible responses. We used multi-actor analysis to analyze parameters of information-sharing network which help highlighting organizations that play a key role in disseminating information and linking actors at different scale and part of different knowledge communities involved directly or indirectly in SRS provision (Section 5.6.2). Concordantly with previous research this analysis finds that the local extension office is connecting actors interested in on-site and off-site benefits of SRS. Moreover, across scales they link also to the scientific communities that design and implement research to respond to SRS degradation. This role is strategic in adaptive governance of SRS and national regulators should reconsider their past decisions in reducing the budget expense in favor of these services.

6.4 Lessons learned for other cases on ES degradation

In this section, the thesis presents conclusions drawn from the Birris watershed case study on SRS that can be applied elsewhere in ES or specifically SRS contexts of developing countries. The Birris case study is defined by its strongly market-oriented
agriculture combined with a high population density dependent on land use-based activities. Moreover, this context can also be characterized, along with the IPCC definition, by its vulnerable context. We can identify processes that increase exposure as indicated by observed and projected increase in the number and/or intensity of extreme precipitation events. Moreover, agricultural activities pose strong pressure on few-left forest resources and, due also to steep slopes, soil resources increasing sensitivity of the system to erosion. Based on these largely defined dimensions of our case study we can draw lessons that might be relevant for other contexts where society in a given landscape strongly depends on the provision of ecosystem services that are threatened by combined societal and climate change impacts. These lessons refer to the methods applied in the thesis to describe, analyze and prescribe actions for planning collective actions to respond to ES degradation.

In developing world, water-related ecosystem services are at the centre of different initiatives aiming at sustaining development (e.g. Millennium Development Goals; national hydroelectricity policies). Protecting or restoring forest cover for its role in water-related ecosystem services in specific watersheds is considered an essential part of these collective efforts although the needed scientific and context-specific evidence to make informed decision is often missing. Generally, this type of information is costly to produce, requires large series of data and, especially considering the complex climate change alteration of hydrological cycle, require thorough analysis and clear communication of uncertainties. In the light of these considerations, some important hints can be given for watersheds of developing countries where, as the Birris case study, large deforestation has already occurred, market-oriented agriculture is well established and high fragmentation of agricultural productive plots can be found. In these types of watersheds, it is difficult to hypothesize the design and implementation of large and extended research project to study the hydrological benefits of increasing forest cover (needed to provide evidence for improved water-related services). Limitations are related to the presence of important agricultural activities that guarantee livelihood of local inhabitants. Thus, considering the above contextual limitations and the uncertainties on the effective hydrological benefits of increasing tree cover, watershed
management plan should strive to foster individual and collective responses to promote the role of agriculture in the provision of on- and off-site ecosystem services. Indeed, agricultural production system can potentially reduce erosion and dam’s siltation by introducing techniques largely known to agricultural scientists and to many farmers.

In this context, the provision of ecosystem services by agricultural systems can be promoted through a combination of complementary policies. While direct economic incentives such as PES schemes has been widely promoted as a means to stimulate individual conservation behaviour, it has been subject of several critics related to social ethics, environmental performance, transaction costs and uncertain opportunity costs mining its economic efficiency. Lessons learned from the Birris case study and the review of results from other cases show that policies and programs supporting technical assistance as well as awareness-raising on causes and consequences of environmental degradation in agricultural landscapes can prove a strong determinant for voluntary conservation behaviour.

The methods and tools used to analyze the cross-scale decision processes of SRS management is applicable to other SRS watershed contexts in developing world as well as to other ecosystem services management situation. In this respect, individual farmers’ decision-making can be studied through a combination of social, economic, territorial and cognitive aspects. To be broadly applicable to different ES contexts, these dimensions need to be adapted to reflect the specific barriers and opportunities that farmers might face in the face and/or perceive of an ES other than SRS. For example, for the case of global ecosystem services such as climate regulation, the perceived opportunities and institutional barriers to access incentives (i.e. transaction costs) from carbon markets might be a very important cognitive factor influencing farmers’ decision to increase tree cover in their farms. Moving at landscape scale, multiple actors influence directly the land use decisions affecting the provision of ES in a specific area. The method proposed in the negotiation analysis chapter of the thesis opens the opportunity for joint gains through the analysis of these actors’ objectives and creation of alternatives shaped by converging interests and values. A possible challenge in the application of this method
in other ES contexts might reside on the synthesis of i) the objectives of multiple actors into creative alternatives to propose for negotiation of mechanism characteristics; and ii) the result of the preference elicitation exercise. This is especially the case of global ES where often land owners (especially forest communities) providing the service of forest carbon sinks live away from potential buyers and these two actors have normally little experience of interaction among them.

6.5 Key messages

Responses to the degradation of Soil Regulation Services require consideration of decision processes happening at multiple scales and facing large uncertainties on the combined effects of land management and climate change. The following thesis’ key messages suggest actions that, at different scales, can promote SRS conservation:

1) At the individual farmer level:
   a. Promote awareness on impacts produced by the interaction of land management and climate change among actors affected by SRS degradation on- and off-site.
   b. Promote support to farmers’ soil conservation behaviour tailored to their specific production contexts (e.g. farm size).

2) At the watershed scale, soil conservation programs should use negotiation analysis to identify key components of a soil conservation program according to both on- and off-site users of SRS. Key components of adaptation responses should include promotion of learning over time (through technical assistance and monitoring) and cost-effective distribution of support (i.e. focusing on erosion priority areas).

3) Finally, national agricultural policies in vulnerable regions should consider strengthening resources endowed to agricultural extension services as these can represent a key actor in the implementation of SRS adaptive management across-scales (i.e. bridging information from farmers to national scientific and policy-making community).
7. Annexes
### Annex 1: Extended acronyms of organizations in the network and their specific mandates

<table>
<thead>
<tr>
<th>Policy Area</th>
<th>Scale</th>
<th>Organization</th>
<th>Mandate relevant for Birris case study</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulatory</td>
<td>National</td>
<td>Regulatory Authority Regulating Public Services (ARESEP)</td>
<td>Ensure adequate quality of public services including water provision to domestic, agricultural and hydroelectric users.</td>
<td>Law of the Regulatory Authority for Public Services. Articles: 5, 6 a) y b), 9, 23 y 25</td>
</tr>
<tr>
<td></td>
<td>National</td>
<td>ARESEP</td>
<td>Regulate tariffs of public services such as electric bill and define items covered by tariffs on electric service including internalization of environmental externalities in watershed management.</td>
<td>Regulation of the ARESEP Law, Art. 5, 6 a), 9, 34, 47-52</td>
</tr>
<tr>
<td></td>
<td>National</td>
<td>National to local</td>
<td>Legitimize the inclusion of costs of watershed management for hydroelectricity production in electric tariff.</td>
<td>Law authorizing Electric Production, Art. 5, 6, 24</td>
</tr>
<tr>
<td></td>
<td>National</td>
<td>National to local</td>
<td>Regulate, fiscal and financial auditing of public service providers such as hydropower.</td>
<td>Ø General Law of Water</td>
</tr>
<tr>
<td></td>
<td>National</td>
<td>National to local</td>
<td>General Law of Water Administration all water resources in the Country. Lead processes for defining national policies on water. Enforce monitoring, control and administration of water in the watershed. Transact national concessions for hydropower production. Operate as information desk for individuals and</td>
<td>Ø Framework Law for the Environment, Art. 50</td>
</tr>
<tr>
<td></td>
<td>National</td>
<td>National to local</td>
<td>Operate as information desk for individuals and</td>
<td>Ø Code for Mines, Art. 4.</td>
</tr>
<tr>
<td></td>
<td>National</td>
<td>National to local</td>
<td></td>
<td>Ø Regulatory Law for Public Services. Transitorio IV.</td>
</tr>
<tr>
<td></td>
<td>National</td>
<td>National to local</td>
<td>Operate as information desk for individuals and</td>
<td>Decree 26635-MINAE. Transfer the Water Dept. To the National Meteorological Institute</td>
</tr>
</tbody>
</table>
Operate as information desk for individuals and government organizations. Audit water and provides concessions to users. Chair the Advisory Board on Water and coordinate member institutions. Charge water tax to users (including hydropower) and define mechanisms for identification of priority areas to invest for ES provision.

<table>
<thead>
<tr>
<th>National to local Ministry of Agriculture and Livestock (MAG)</th>
<th>Promote research on hydrological, hydrogeological, agricultural activities and their relation with surface and underground water. Certificate rational soil and water use in irrigation concessions. Audit through technical studies the appropriate management of soil and water and transmit information to Ministry of Environment (MINAE) for correspondent eventual cancellation of concessions. Audit, evaluate technical studies for definition of appropriate agricultural uses and zoning of rural areas to define appropriate management according to environmental, social and agricultural use. Define and coordinate implementation of national soil conservation plans in collaboration with relevant agricultural organizations. Implement research to improve land and resource management.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1949 Creation of the MAG</td>
<td>Ø Law N° 7779 for Use, Management and Conservation of Soil, Art. 6 y 33</td>
</tr>
<tr>
<td></td>
<td>Ø Regulatory Law for Use, Management and Conservation of Soil</td>
</tr>
<tr>
<td></td>
<td>Ø Regulation for the Control and Registration of Dangerous Products Art. 4 y 12</td>
</tr>
<tr>
<td></td>
<td>Regulation for Use, Registration and Control of Pesticides Art. 2 y 66</td>
</tr>
<tr>
<td>1995 Decentralization process under World Bank financing to privatize some services provision and creating three main divisions: Technology research; Extension services in</td>
<td></td>
</tr>
</tbody>
</table>
Promote training to all levels for increasing transfer of appropriate technologies for land use and management; This was formed for analysis and discussion of agricultural policy-making.

Provide technical assistance to agricultural producers to promote appropriate land management.

Provide criteria to evaluate consequences of different water uses including hydropower and agriculture on soil resources.

Keep registers of and monitor organizations and individuals implementing soil conservation activities.

Maintain a data bank with registers of soil management and land use capacity including information on socioeconomic, technical and environmental aspects.

Promote constantly participation of civil society in soil conservation activities through its decentralized extension offices such as ASA-MAG Pacaya.

The creation of the National Inter-organizational Forum for Agriculture, Executive Decree Nº 31170-MAG, 2003.

Consolidated National Network for Conservationist Agriculture with organizations as MAG, ICE, ITCR, CNFL, UNED, UCR, UNA, to strengthen research and development of conservationist agriculture.

Elaborated the Agricultural Strategy 21 with Support of IICA office in Costa Rica

The National Program to Promote Sustainable Agriculture was started with IADB loan 1436/OC-CR(MAG/BID) PFPAS.

Law 7174 1990 (Executive Decree N. 19886-MIRENEM;

Norm N032, Law 7216, 1991, Creation of the fund

Law 7575, Art. 46 creation of FONAFIFO
<table>
<thead>
<tr>
<th>National to local</th>
<th>National System for Protected Areas (SINAC-MINAE)</th>
<th>Law 7575, Art. 46 creation of FONAFIFO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decentralized and participatory organization integrating forestry, wildlife and protected areas departments of MINAE.</td>
<td>Define criteria for identification of priority areas where funding should be targeted; Ensure appropriate funding to promote provision of appropriate level of ES; Define and implement mechanisms for fund assignment.</td>
<td>Law of Creation of National Service for Protected Areas, Art. 13.</td>
</tr>
<tr>
<td>Establish alliances with relevant actors to promote watershed protection.</td>
<td></td>
<td>Ø Biodiversity Law, Art. 22, 25 y 59.</td>
</tr>
<tr>
<td>Define and enforce rules to regulate land use in protected areas.</td>
<td></td>
<td>Framework Law of the Environment, Art. 34.</td>
</tr>
<tr>
<td>Take part in the local advisory board.</td>
<td>Ø Decree N. 26635-MINAE: Art.. 5 y 7 Creation and Function of the Advisory Entity for Water</td>
<td>Ø Decree N° 26624-MINAE</td>
</tr>
<tr>
<td>Promote processes of organizations implementing soil conservation activities.</td>
<td>Ø Water Law, Art. 31, 41, 154-158, 177, 194-198</td>
<td>Ø Municipal Code, Art. 4 c), 6, 13 d), 79 y 81</td>
</tr>
<tr>
<td>Enforce local decrees and concessions to protect forests and water sources in watershed planning.</td>
<td></td>
<td>Ø General Drinking Water Law, Art. 4, 5, 6, 7 10 y11.</td>
</tr>
<tr>
<td>Evaluate and provide approval of watershed management plans.</td>
<td>Enforce rules</td>
<td>Ø Law of Creation of AYA Art. 20 y 22</td>
</tr>
<tr>
<td>Design, plan and implement policies for sustainable natural resource management.</td>
<td></td>
<td>Framework Law of the Environment, Art. 60</td>
</tr>
<tr>
<td>Recommend appropriate legal enforcement for protected areas.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enforce rules</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Protect and conserve watersheds and water resources.

Ø Law of Urban Planning, Art.15 y 28. Establish municipal enforcement to regulate urban planning and development. This is related to the art. 52 of the Biodiversity Law and 28 of the Framework Law for the Environment Law for Construction Art. 1 and 3 providing guidance on construction of infrastructures.

Ø Decree N. 26635-MINAE: Art.. 5 y 7 Creation and Function of the Advisory Entity for Water

Ø Water Law, Art. 31, 41, 154-158, 177, 194-198

Ø Decree N° 26624-MINAE

Ø Municipal Code, Art. 4 c), 6, 13 d), 79 y 81

Ø General Drinking Water Law, Art. 4, 5, 6, 7 10 y11.

Ø Law creating AYA, Art. 20 y 22

Ø Framework Law of the Environment Art. 60 Ley de Construcciones Art. 1 y 3: Sobre los permisos para la construcción

Law 7121,1991; creation of CIA

Modification of Art. 52 and 59 of Law 7121

Ø Law N° 6877 Creation of the National Service for Underground Water, Art. 3

Ø General Regulation for SENARA.

Ø Regulation for SENARA control of irrigation water

Biodiversity Law, Art. 114
<table>
<thead>
<tr>
<th>Demand</th>
<th>National to watershed</th>
<th>National Institute for Electricity (ICE) and departments such as PISA, Environment, Projects and decentralized offices such as the Reventazon Watershed Management Unit (UMCRE)</th>
<th>Ø Law N° 449 for the creation of the National Institute for Electricity (ICE), Art. 1, 2, 16 demanding to foster exploitation of energy sources in the country, while sustainably using hydropower potential and protecting watersheds.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watershed</td>
<td>Cartago Administrative Board on water (JASEC)</td>
<td>Provide for rational use of water resources for energy production. Conserve water resources through activities for watershed protection. Hydropower user of ecosystem water services, benefits from upstream erosion control for operating its downstream plants. Promote sustainable use of water resources in the Birris watershed. Training to schools and producers on benefits of reforestation.</td>
<td>Law N° 7200 authorizing private generation of electricity, Art. 7</td>
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<td></td>
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<td>Law 3300, 1964; creation of the Board to administrate Municipal Electric Company</td>
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<td>Law 7420, 1994; Concession for using water for hydropower generation in Birris Watershed</td>
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<td></td>
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<td>Law 8345, 2003; Allowing JASEC to operate hydropower plants all over national territory</td>
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</table>
|                               |                                        | Formal Agreement with ICE-UMCRE for farmers'
<table>
<thead>
<tr>
<th>Role</th>
<th>Location</th>
<th>Activity</th>
<th>Legislation/Source</th>
</tr>
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<tbody>
<tr>
<td>Supply</td>
<td>Watershed Commission</td>
<td>Promote Establish the watershed management plan through formation of a committee to foster watershed protection through soil and water conservation. Collaborate with other local organizations such as ASA-MAG Pacaya to implement the plan.</td>
<td>Law N° 8023 Planning and Management of the Upper Reventazon Watershed, Art. 4, 5, 6</td>
</tr>
<tr>
<td></td>
<td>Local</td>
<td>Elaborate, implement and control the watershed management plan for Upstream Reventazon Watershed with emphasis on water services.</td>
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<tr>
<td></td>
<td>National</td>
<td>Define and implement training activities with communities and personnel of organizations on watershed planning. Implement activities in priority areas providing ecosystem services.</td>
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<tr>
<td></td>
<td>National Institute</td>
<td>Personal interviews</td>
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<td>for Autonomous public institution with mandate to implement national</td>
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Promote activities to enhance market and financial access of producers. Promote training of producers on innovative techniques to sustainably manage soil in farms.

Local Producer associations (ADAPEX, ADICO, COOPEB AIRES)

National National Institute for

Law 6735, 1982; Creation of IDA
<table>
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<tr>
<th>National to watershed</th>
<th>National Council for agricultural production (CNP)</th>
<th>Autonomous institute ascribed to MAG, with mandate to:</th>
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<tr>
<td></td>
<td></td>
<td>Foster activities that increase market and financial access of producers;</td>
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<td></td>
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<td>Promote activities and strategies that improve national food security and socioeconomic well-being of producers;</td>
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<tr>
<td></td>
<td></td>
<td>Support dissemination of technological innovations in production, industrialization and marketing;</td>
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<td></td>
<td></td>
<td>Support import and export of agricultural producers focusing on small to medium farmers;</td>
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<td></td>
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<td>Establish partnerships with extension and technical assistance programs;</td>
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<tr>
<th>National</th>
<th>National Institute for Social Welfare (IMAS-regional)</th>
<th>Formulate and implements policy</th>
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<tr>
<td></td>
<td></td>
<td>Law Nº 4760 Creating the Mixed Institute for Social Support and its regulation decree Nº 26940-MIVAH-MTSS</td>
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|          |                                                       | Law 2825, 1982; Regulation of Land use to foster ES provision and tenure rights |
|          |                                                       | Law of the National Producers Council reformed by Law 6050 and by Law nº 7742. |
guidelines to combat poverty including financing initiatives that through appropriate land management promote social welfare and environmental benefits.

Support producers affected by climate extremes.

Support with small subsidies poor producers that in collaboration with local ASA-MAG Pacaya extension office use appropriate soil management techniques. Establish alliances with other relevant actors to achieve its goals of poverty reduction. Inter-governmental Commission formed by representant of national technical institutes on climate change and hydrometeorology of Central American region, promoting: sustainable use and conservation of water resources through dissemination of technical studies.

Communicating to large public and organizations on climate change and vulnerability water resources and its users. Identify, coordinate and facilitate processes and programs related to water resources in Central America. Strengthen the links between regional programs and international initiatives dealing with climate change, variability and water.

Law Nº 7742 creates the program for agricultural sector production reform modified by Law 8563. Regulates provision of resources to support the national plan for agricultural production reconversion.

<table>
<thead>
<tr>
<th>Science</th>
<th>International Committee for water resources (CRRH)</th>
<th>Tax-sources for poverty reduction</th>
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<tr>
<td></td>
<td>Formal creation 1966</td>
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<td></td>
<td>Formal Agreement with Regional IUCN headquarter to foster initiatives on climate change adaptation in water resources and support regional participation in Copenhagen COP</td>
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<td></td>
<td>Creation in 1948 under the Organization of the American States (OAS)</td>
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<tr>
<td>International to National</td>
<td>Regional Institute for Agriculture Cooperation (IICA)</td>
<td>Part of Organization of American States, it is an intergovernmental organization with mandate to:</td>
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<td></td>
<td>Promote well-being of rural population;</td>
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<td>Promote dialogue and consensus on key issue for agricultural development of Latin America;</td>
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<td></td>
<td></td>
<td>Disseminate results from research centres on agriculture and its vulnerability to climate change impacts;</td>
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<td>Promote national campaigns on climate change and adaptation in water resources management with emphasis on the role of ecosystems for society.</td>
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<tr>
<td></td>
<td></td>
<td>Disseminate information on climate change and variability impacts on ecosystems and the services they provide.</td>
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<tr>
<td></td>
<td></td>
<td>Support and promote research to improve knowledge on ecosystem and their services.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Establish alliances with national and international partners to foster research, transfer and dissemination of results</td>
</tr>
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</table>

**Internation**

**al to National**

**Regional Institute for Agriculture Cooperation (IICA)**

**Part of Organization of American States, it is an intergovernmental organization with mandate to:**

- Promote well-being of rural population;
- Promote dialogue and consensus on key issue for agricultural development of Latin America;
- Disseminate results from research centres on agriculture and its vulnerability to climate change impacts;
- Promote funding for research organizations to implement appropriate technical responses to impacts of climate extremes.
- Promote national campaigns on climate change and adaptation in water resources management with emphasis on the role of ecosystems for society.
- Disseminate information on climate change and variability impacts on ecosystems and the services they provide.
- Support and promote research to improve knowledge on ecosystem and their services.
- Establish collaborative partnerships to foster regulatory changes for ecosystem protection.

**Creation in 1948 under the Organization of the American States (OAS)**

- In 2000 OAS decision to make IICA the governing body of the Inter-American Board for Agriculture with mandate to improve rural life with sustainable production in agriculture.

**Internation**

**al to national**

**Regional /national civil society (IUCN)**

**Part of Organization of American States, it is an intergovernmental organization with mandate to:**

- Promote well-being of rural population;
- Promote dialogue and consensus on key issue for agricultural development of Latin America;
- Disseminate results from research centres on agriculture and its vulnerability to climate change impacts;
- Promote funding for research organizations to implement appropriate technical responses to impacts of climate extremes.
- Promote national campaigns on climate change and adaptation in water resources management with emphasis on the role of ecosystems for society.
- Disseminate information on climate change and variability impacts on ecosystems and the services they provide.
- Support and promote research to improve knowledge on ecosystem and their services.
- Establish collaborative partnerships to foster regulatory changes for ecosystem protection.
- Establish alliances with national and international partners to foster research, transfer and dissemination of results.

**1948 creation of IUCN as an international NGO for Nature Conservation**
<p>| National to local | National Initiative on Peace with Nature (IPN) | Inter-organizational commission formed by nine ministers and the president with mandate to organize and coordinate emergency responses. Disseminate information on areas vulnerable to climate extremes through decentralized local committees. Support organizations fostering watershed protection activities that prevent natural disasters. Governmental initiative led by the Executive Office of the Presidency Ministry with an Presidential commission composed by 25 members from academic, private, civil society and public organizations. Promote policy processes to counter arrest environmental degradation through public and private partnerships. Advocate processes for land use planning accounting for priority areas for ecosystem services provision. Promote reforestation and increase in protected areas. Support national programs to fund native forests. Support the formulation and implementation of the National Strategy on Climate Change (ENCC). Promote dissemination of climate change policies and studies to large public and relevant organizations. Foster initiatives to | Law N° 8488 provides CNE the enforcement to promote disaster prevention and preparedness. 6 June 2008 Presidential Launch of the Initiative IPN to combat environmental degradation Initially was presented by Executive Decree No. 33487-MP and establish a Presidential Commission with 25 members and a High Level Committee. It is ascribed to the Ministry for the Presidency and mandates public organizations to take actions to protect the environment. |</p>
<table>
<thead>
<tr>
<th>National to local</th>
<th>National Institute for Technological Innovation in Agriculture (INTA)</th>
<th>Promote research on the field for innovation in agriculture</th>
<th>In 1999 the former Technical Research office of MAG is transformed in INTA</th>
</tr>
</thead>
<tbody>
<tr>
<td>National</td>
<td>Agronomic Research Centre of the University</td>
<td>Disseminate results together with MAG decentralized extension offices. Validate appropriate soil management techniques to prevent erosion. Implement basic and applied research on soil science also through alliances with local producers’ associations or agricultural extension.</td>
<td>Personal Interviews</td>
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<td></td>
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<td>Formal Agreement with MAG, 1 dec. 1950; Formal creation by UCR faculty decree, 1971</td>
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<td></td>
<td>National Institute for Meteorology (IMN)</td>
<td>Protect Ecosystem Services in land use planning for their importance for development and adaptation to climate change. Scientific and technical Institute ascribed to MINAE.</td>
<td>1988 Creation of IMN</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coordinate meteorological data collection analysis and dissemination. Implement research on climate change and variability, and in collaboration with other organizations studies on impacts and vulnerability of water resources and of coastal, agricultural, biodiversity and health sectors. Coordinate the recompilation of the National Communication and is part of the National Delegation to UNFCCC.</td>
<td>Law N° 5222 created the IMN under MAG. Afterwards, Law N° 7152 in 1990 transfers IMN to MINAE.</td>
</tr>
<tr>
<td>National Program for National Strategy on Climate Change (ENCC)</td>
<td>Disseminate results through technical pamphlets or scientific articles in national and international journals. Develop and update databases of information on natural resources in Costa Rica. Provide technical assistance for specific environmental management problems related to agriculture. <strong>Promote policies to mitigate GHG with national activities (bio-fuels, increase energy use efficiency, promote low carbon energy such as hydro, wind, solar, and geo-thermal power). Promote adaptation to climate change and variability in water, agricultural, coastal, health, biodiversity and infrastructure policies. Support initiatives to raise social and human resources to reduce climate change and its impacts.</strong> <strong>Promote awareness in civil servants and public in general on climate change and its impacts and solutions.</strong> Identify the need for information networks creation in order to foster</td>
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<tr>
<td>Web site (<a href="http://www.encc.go.cr/">http://www.encc.go.cr/</a>) and interviews.</td>
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<tr>
<td>National Program for Integrative Environmental Management of the University of Costa Rica (PROGAI-UCR)</td>
<td>2005 the PROGAI is established in UCR</td>
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<td>12-15 Feb 2008 first National Congress PROGAI-UCR final declaration states importance of preventive ecosystem management to revert degradation and foster development and that establishing partnerships is important for fostering sustainable watershed management</td>
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<tr>
<td>Watershed ASA-Pacayas Ministry of Agriculture (MAG)</td>
<td>The 2004 XIV Summit of Ibero American Governments supported the creation of rural centre to support training and promotion of sustainable agricultural production systems</td>
<td></td>
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<tr>
<td>Decree 31623 MAG-H, 2003; defining priorities and execution of funding for technical assistance</td>
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- Promote research on appropriate management of ecosystems with special emphasis on water resources.
- Promote national events for dissemination of research results on water and watershed management.
- Promote national processes for design of water related policies.
- Local extension office of the MAG promoting diffusion of technical information on soil management, takes part to regional committees to reduce impacts of climate-extremes on agriculture.
- Promote and supports collaborations with research projects on strategies to improve soil management and provides transfer to farmers.
- Promote awareness campaigns on environmental degradation.
- Establish alliances with individual farmers and/or farmers' associations to promote soil adaptation.
| National Advisory Commission on Degraded Lands (CADETI) | Inter-organizational commission under MINAE and MAG integrated by representatives from academic organizations, NGOs, MINAE, IMN, MAG technical conservation offices. Formulate and evaluate the National action plan on Degraded lands. | Executive Decree № 27258-MINAE creates CADETI as focal point to UNCCD mandating the design of related actions at national level, and the elaboration of National Plan to Combat Land Degradation and Desertification. |

Advise National Focal Point to United Nations
Annex 2. Ecosystem-based adaptation to climate change: what role for policy-makers, society and scientists?


Abstract
In developing countries where economies and livelihoods depend largely on ecosystem services, policies for adaptation to climate change should take into account the role of these services in increasing the resilience of society. This ecosystem-based approach to adaptation was the focus of an international workshop on "Adaptation to Climate Change: the role of Ecosystem Services" held in November 2008 in Costa Rica. This article presents the key messages from the workshop.

Keywords: Adaptation to climate change, ecosystem services, policy-science-society dialogue.

A 2.1 Introduction

An international workshop on “Adaptation to Climate Change: the role of Ecosystem Services” was held in November 3-5, 2008 in the International Centre for Tropical Agriculture Research and Higher Education (CATIE) in Turrialba, Costa Rica. The 80 participants came from 24 countries (mostly Latin American) and 56 institutions (local communities, NGOs, scientific organizations, government agencies, public and private firms, and international agencies for cooperation) to discuss the role of ecosystem services in adaptation to climate change.

While most developing countries’ economies depend largely on natural resources and ecosystem services, the capacity of ecosystems to provide services to sectors of the society is pressured by land use change and climate change. As adaptation is needed for the sectors of society facing the impacts of climate change, it is necessary to consider the vulnerability and role of ecosystems in sustained provision of ecosystem services to these sectors.

The aim of this article is to present the key messages that the participants discussed during the workshop. These key messages are targeted at the stakeholders that can design and implement ecosystem-based adaptation (EBA). We define ecosystem-based adaptation as the adaptation policies and measures that take into account the role of ecosystem services in reducing the vulnerability of society to climate change, in a multi-sectoral and multi-scale approach. EBA
involves national and regional governments, local communities, private companies and NGOs in addressing the different pressures on ecosystem services, including land use change and climate change, and managing ecosystems to increase the resilience of people and economic sectors to climate change. The concept of EBA has emerged recently in the international climate change arena, with countries (e.g., Colombia, Sri Lanka), groups of countries (e.g., the African Group) and observers (e.g. the International Union for Conservation of Nature) addressing EBA in their submissions to the United Nations Framework Convention on Climate Change.

A 2.2 Content of the workshop

The workshop included seven sessions. The first session aimed at updating participants on the main concepts and issues related to ecosystem services, adaptation to climate change, and EBA. The second session aimed at communicating results of scientific studies related to the vulnerability of ecosystems and ecosystem services in Latin America. Discussion topics addressed different dimensions of ecosystem vulnerability: exposure (climate change scenarios), sensitivity (e.g. the impacts of climate change on protected areas, hydrological ecosystem services or forest fires), and adaptive capacity (e.g. the role of landscape connectivity in ecosystem adaptation). The third session addressed the role of ecosystem services (e.g. hydrological services for sectors depending on water, such as drinking water and hydropower production).

During the fourth session, attendees reviewed experiences of policies and measures for adaptation at local, national and regional levels. Even though the impacts of climate change and the role of ecosystem services are uncertain, no-regret policy responses can benefit both climate change adaptation and sustainable ecosystem management. The fifth session aimed at exploring communication strategies regarding adaptation to climate change. Establishing an efficient dialogue between scientists, decision makers and civil society is challenging but necessary for EBA. This dialogue should start at the stage of research design and be pursued until the communication of research results and uncertainties.

During the sixth session, financial mechanisms for adaptation or for the management of ecosystem services were reviewed. Innovative financial mechanisms are needed for these processes, but remain challenging because of the complexity of evaluating adaptation costs and benefits, and the sensitivity of political negotiations related to international adaptation finance.
The seventh session was aimed at sharing experiences of public and private initiatives of ecosystem management and conservation. As these initiatives are seldom explicitly linked with climate change adaptation, their role in reducing the vulnerability of ecosystems and society needs to be further analyzed.

The participants presented a wide array of perspectives and experiences related to ecosystem services and adaptation to climate change in Latin America, including community management, payment for ecosystem services, and insurance schemes. These experiences allowed participants to discuss crucial issues such as the need for institutional changes for adaptation, a better understanding of uncertainties and strategies to cope with them, improved dialogue between scientists and decision makers, and strengthened linkages between sectors and scales, from local to global levels.

At the end of the workshop, the participants worked in groups to elaborate key messages directed at three groups of stakeholders in EBA: (1) national policy-makers (2) local communities, private sector and others members of civil society, (3) scientists (Figure 1).

Figure 1: Key messages to stakeholders related to ecosystem-based adaptation (EBA)
A 2.3 Key messages for national policy-makers

Mainstream adaptation and ecosystem services into national policies. Ecosystem degradation and vulnerability to climate change are development issues rather than strictly environmental problems. As the loss of natural capital and the associated vulnerabilities are a threat for sustainable development, national development policies should integrate ecosystem management and adaptation to climate change. Multi-sectorial and cross scale approaches are needed for mainstreaming both adaptation and ecosystem services into policies. Policy-makers should create and enforce linkages between ecosystem managers and vulnerable sectors benefiting from ecosystem services. Moreover, education and outreach policies should raise societal awareness about the relevance of ecosystem services and adaptation for sustainable development.

Develop innovative funding. Because of market failures, current regulations fail to conserve ecosystem services that are valuable for society. Thus, sectors benefiting from ecosystem services should be involved in funding ecosystem management or conservation. Payment for Ecosystem Services (PES) is an innovative mechanism being developed in several Latin American countries in both governmental and private initiatives. PES can complement international adaptation funding sources in cases where the users of ecosystem services are willing and able to provide resources for protecting these services. The challenge for policymakers is to create an institutional environment that facilitates agreements between users and providers of ecosystem services.

Influence international policies. International negotiations on development and environmental issues can influence national policies on adaptation and ecosystems and thus EBA design. Policy-makers should therefore ensure that the outcomes of negotiations in this arena include adequate consideration of ecosystem services that are priorities for their national development and adaptation. To enforce their positions in these negotiations, it is strategically important that policy-makers strengthen their understanding of the challenges implied in designing and implementing EBA. This might be especially relevant in the context of the negotiations defining the terms of reference and the management of the Adaptation Fund where investment priorities are defined.
Strengthen the links between adaptation and mitigation. Mitigation instruments, such as the Clean Development Mechanism or the currently discussed REDD (Reduction of Emission from Deforestation and Forest Degradation) can provide benefits for both mitigation and adaptation, as they contribute to conserving and restoring ecosystem services. However, some concerns have been raised about the potential negative impacts that some mitigation projects may have on local development and biodiversity. Thus policymakers should try to foster synergies between mitigation and adaptation by developing and applying guidelines or standards for mitigation projects. These standards could provide guidance to mitigation project developers willing to address adaptation and enable policymakers or donors to assess the contribution of mitigation projects to adaptation.

Interact with local communities. Local communities are important decision-makers in adaptation and ecosystem management. National policymakers should empower local and indigenous communities to facilitate adaptation processes that take traditional knowledge into account. EBA policies should recognize the diversity of local situations and create a facilitating environment for effective local adaptation and ecosystem management. Policies should also promote environmental education for promoting EBA in local communities.

Interact with scientists. Understanding climate change impacts and vulnerability is a complex task, and technical expertise is required to understand and interpret the results of scientific studies. It is therefore important that, for building no-regret policies, policy-makers interact with scientists to take into account uncertainties inherent in climate change studies. Policy-makers should create institutional arrangements and funding sources to facilitate the development and use of relevant social and natural science knowledge into policy processes.

A 2.4 Key messages for communities, local actors and others members of civil society

The following messages are addressed to the variety of stakeholders that manage ecosystems, implement adaption, or use ecosystem services, such as local communities, the civil society and the private sector.

Define and implement adaptation. Even though national policies influence local processes, adaptation eventually happens locally. Local actors have the responsibility to promote EBA, given their direct interest in ecosystem health and provision of services. Communities should design
and implement strategies for ecosystem-based adaptation as part of their local resource planning. Civil society and communities should increase their capacity to negotiate and establish equitable partnerships with a variety of actors (public and private) acting at different scales of decisions. NGOs can play a role in strengthening indigenous populations in protecting their rights and values in the design of adaptation plans.

**Reward ecosystem service providers.** Local communities, civil society and private actors should reward actors that conserve or restore ecosystem services. This would enable restoring services, or preventing future land use changes and loss of services. Innovative mechanisms, such as PES, may be an important component of ecosystem-based adaptation.

**Interact with policy makers.** Policy makers set the institutional context in which ecosystem-based adaptation can take place. The interests, obstacles and capacities of local communities, however, are not always reflected in national and local policies. A key role for civil society is then to empower the capacity of local actors to participate in policy-making at both local and national levels. Building capacity and opening spaces for participation in policy making can be a way to achieve these goals.

**Interact with scientists.** Research on ecosystems services and how they can reduce societal vulnerability to climate change is a relatively new field characterized by complexity and uncertainty. In this context, local knowledge on ecosystems and their management should be respected and is crucial for improving scientists’ understanding and their capacity to support design of appropriate responses. In this respect, interaction with social scientists is important given their expertise on integrating different knowledge-systems into collaborative efforts. Local communities and civil society are thus called to play a more active role, getting involved in field research and informing scientists on observed changes and local adaptation, and scientists should adapt their methods to use these resources. In addition, private sectors could also finance science, as they also could benefit from new scientific knowledge on adaptation and ecosystem services.

A 2.5 Key messages for scientists

**Quantify and value ecosystem services.** Several international scientific initiatives such as the Millennium Ecosystem Assessment have acknowledged the relevance of ecosystem services for
human wellbeing. However, more evidence is needed on the role of ecosystem services in reducing the vulnerability of society, as well as the costs and benefits of conserving ecosystem services, in the context of climate change. Quantification and spatial prioritization of ecosystem services for adaptation are also needed for adaptation.

**Evaluate uncertainties.** Ecosystem services and climate change impacts assessments deal with complexity and uncertainty; therefore, their recognition and evaluation is essential for designing adaptive approaches to EBA. Impact or vulnerability studies should always include an analysis of sensitivity, for instance, using different models and different climate scenarios. In an adaptive process, uncertainty analysis also enables the identification of which variables are uncertain and determinant in explaining vulnerability to climate change. These variables can be transformed into indicators for monitoring trends in the field.

**Work at local scales.** Many climate change impact studies or vulnerability assessments show results on regional and global scales, providing a broad view that seldom helps interested parties to design local adaptation. For instance, EBA requires identifying the flow of ecosystem services in local landscapes, as a tool for determining land uses that may provide ecosystem services relevant to the adaptation of society. Thus, more research is needed to address scientific issues related to EBA at a local scale. In addition, social scientists have an important role to play in understanding local social processes relevant for adaptation and ecosystem conservation.

**Communicate results to non-scientists.** Scientists should devote substantial efforts in communicating research results to non-scientists, such as local NGOs, public administration and the media, in order to increase their capacity to influence the implementation of EBA. Strategic alliances with experts from communication sciences should be considered as a key component of research projects on EBA.

**Interact with local communities and private sector.** Scientists studying climate change impacts and the design of EBA measures are called to work closely with local communities and the private sector in order to understand local processes of adaptation and ecosystem management. Scientists should also involve local communities and private sectors from the early stages of research design, so that scientific work and results can serve local EBA design and implementation.
Interact with policymakers. Scientists producing knowledge on climate change impacts and EBA measures should ensure that results are communicated in a way that is relevant to policymakers. At the local and national levels, scientists should participate, as one of the stakeholders, in policy design process, including problem identification, strategy formulation, selection of policy options, monitoring and evaluation. At global level, scientists can play an important advisory role to national policy-makers who participate in international negotiations related to adaptation and possibly to EBA.

A 2.6 Conclusions

Increasing attention has been paid to the complex interactions between human and environmental systems, especially regarding the conservation and management of ecosystem services. However, the role of ecosystem services in supporting adaptation to climate change is a relatively new issue in the scientific arena, and even more so in the policy arena. In order to promote the role of ecosystem services in societal adaptation to climate change, it is important that a variety of actors, such as policy-makers, scientists and civil society, are actively involved in accordance with their mandates. The key messages presented in this article are not only relevant for Latin America but are valid also for other regions, especially where people depend strongly on natural resources.
Acknowledgments

In long journey of this thesis I have met and collaborated with many people that have shared with me their knowledge and friendship, and have contributed to my professional and personal growth. First of all, I want to acknowledge the support given to join the PhD program at ETHZ by Dr. Lucio Pedroni, leader of the Climate Change Program at CATIE at the moment of PhD start date. He has given me the opportunity to participate in the TroFCCA project where my understanding of global change phenomena has been fed by intense exchange of theories, knowledge and methods that have inspired my research in the PhD. I want to thank Bruno Locatelli whom during the initial years at the CATIE has shared his knowledge and the friendship of his warm family. I acknowledge Pablo Imbach, a friend from the very start and a colleague sharing motivations and perspectives on professional aspects as well as the positive and negative moments of our PhD studies. I acknowledge professor R.W. Scholz for the inspiring discussions had during our meetings. For his support and for opening the opportunity to join his group at ETHZ where I met people that have been friends and teachers to me while sharing methods and theory of interdisciplinary science, so needed especially in developing world contexts. I would also like to acknowledge Maria Rey for her kind support throughout my studies at ETHZ. I thank Professor Thomas Koellner for his friendship and support in many journeys to Zurich. I thank him for his support in the developing of ideas and opportunity for this PhD; from the very start Thomas has been an important motivator along the ups and downs of this research.

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I want to thank also my family in Italy for always being there and making the Atlantic Ocean and the Mediterranean Sea disappear when we talk, and the days and months separating our visits disappear when we meet. Finally, I want to thank the two treasures of my life Sofia Manuela and Jimena whom make my life a continuous motivation to improve my character and an inspiration to give more to others.
Curriculum Vitae

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1969  Born in Salerno, Italy
1982-1987  Scientific Lyceum, Eboli, Salerno, Italy
1987-1996  Study at University of Agriculture, Florence, Italy
1994  Field-studies in Ecology Tamil Nadu, India
1997  Scholarship Agro-Meteorological Institute, University of Florence, Italy
1998  Fellowship at Institute for the Overseas, Ministry of Foreign Affairs, Italy
2000  Consultant on Watershed Management Planning, Honduras
2001-2003  Coordinator EU Disaster Prevention Project DIPECHO II, El Salvador
2003-2004  Study Master of Science in Environmental Economics, Centre for Higher Education and Training for Latin America (CATIE), Costa Rica
2004  United Nations Operation Program (UNOPS)-Central American Program to Fight Poverty, Consultant Socio-economic impacts of environmental pollution, El Salvador
2005-2010  Researcher/professor of Climate Change Program at CATIE, Costa Rica
2007-2010  PhD studies at ETH-NSSI with CATIE
2010-2012  Co-investigator research project: Human Dimension of Soil Regulation Services under climate change in Costa Rica, Climate Change program-CATIE/Institute for Resources and Sustainability-University of British Columbia, Canada

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