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Payments for Environmental Services in the Campohermoso watershed

Measuring opportunity costs and identifying determinants

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Abstract

The policy instrument Payments for Environmental Services (PES) is spreading rapidly around the globe as a means for conservation planners to offer direct economic incentives to landowners for providing environmental services. To supply environmental services, landowners incur costs which should be compensated and estimating these costs lies at the very heart of an efficient conservation program. In support of the development of a PES project in the Campohermoso watershed in Colombia, 114 farms were surveyed regarding their own perceived value of the property. A hedonic method was used to infer land values for all land plots in the study area based on land characteristics and access to markets. The opportunity cost of conservation for farmers in the Campohermoso watershed was determined to be US$877 per hectare per year on average. However, the regression analysis revealed that opportunity costs to conservation vary considerably between properties and are dependent on the environmental and spatial characteristics of the plot. Targeting properties with low cost but high additional service provision can therefore increase efficiency significantly. Offering differentiated payment to participants based on potential service provision may also successfully increase the performance of the PES project in the Campohermoso watershed.

Resumen

El instrumento económico llamado Pagos por Servicios Ambientales (PSA) se está extendiendo rápidamente por todo el mundo como un medio para que los planificadores de la conservación ofrezcan incentivos económicos directos a los propietarios por la prestación de servicios medioambientales. Para proveer servicios ambientales, los propietarios incurren en gastos que deben ser compensados y cuya estimación constituye el núcleo de un programa eficaz de conservación. En apoyo al desarrollo de un proyecto de PSA en la cuenca de Campohermoso, Colombia, 114 granjas fueron estudiadas desde el punto de vista del propio valor, tal como es percibido por sus propietarios. Para inferir valores de la tierra en todas las parcelas en el área de estudio, basados en las características de la tierra y el acceso a los mercados, se utilizó un método hedónico. El coste de oportunidad de la conservación para los agricultores de la cuenca de Campohermoso se determinó en un promedio de 877 dólares estadounidenses por hectárea y por año. Sin embargo, el análisis de regresión reveló que los costes de oportunidad de conservación varían considerablemente entre las propiedades y dependen de las características ambientales y espaciales del predio. Seleccionar las propiedades con un bajo coste, pero de alta provisión de servicios adicionales, puede aumentar la eficiencia del programa. Ofrecer pago diferenciado a los participantes sobre la base de la prestación de servicios potenciales también puede aumentar el éxito del proyecto de PSA, en la cuenca de Campohermoso.

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Introduction

Environmental services are a set of amenities provided by natural or managed ecosystems that may directly or indirectly benefit society. The concept was popularized by the United Nations' Millennium Ecosystem Assessment (MEA 2005), who grouped environmental services into four broad categories: *provisioning*, such as production of clean drinking water; *regulating*, such as controlling climate and water flows; *supporting*, such as crop pollination; and *cultural*, such as recreational benefits like scenic beauty.

Individuals managing their lands may not take these positive externalities into account in their economic decisions, and as a result provide less environmental services than what is economically efficient from a social planner's perspective (Kosoy, Martinez-Tuna et al. 2007). To supply environmental services, landholders may incur two main types of costs; initial investment costs for meeting conditions for participation (e.g. build a fence) and opportunity costs through foregone income from land under conservation. There is thus a reason for landholders to be compensated, which is the foundation for the policy instrument Payments of Environmental Services (PES), a policy instrument used to offer economic incentives to landowners in exchange for managing their land to provide environmental services.

Incorporating cost considerations early in the PES planning process is crucial for the program outcome. Payments to landowners must be set at a level that attracts an appropriate level of participation by environmental service providers (sellers). If payments are too low, conservation goals may not be fulfilled. If payments are too high, funds have probably been used inefficiently. Even if knowledge about the landowners' opportunity cost is critical, it is usually not known to the conservation planner. Estimating these opportunity costs is important for providing a solid framework for determining the payment levels.

Furthermore, the PES policy has been promoted as a tool for rural development and poverty alleviation. Sellers are often found in up-stream marginal lands, while those who benefit from environmental services (buyers) reside in urban centres or valleys with more productive agricultural land. A redistribution of incomes could in theory reduce poverty (Pagiola, Arcenas et al. 2005). Scarce water sources may become a devastating threat to future development if conflicts over water use are intensified. Policy interventions at an early stage that improve the management of scarce natural resources can secure continued supply of environmental services and support the future growth of the region.

This study aims to gather information on the opportunity cost of sellers in a Colombian PES project being developed in the eastern mountain range of Colombia. Water is becoming an increasingly scarce resource and paying local farmers for more environmentally friendly land use has been identified as a cost-effective means of achieving better water quality and quantity. Opportunity costs of farmers to deliver environmental services are predicted using a quasi-hedonic model that defines land characteristics as input into production. Land values are regressed on plot characteristics, production activities, market access and socio-economic factors. An opportunity cost map is then produced which demonstrates the diverse costs of conservation in the region.

Section 1.

1.1 Payments for Environmental Services – A clarification of concepts

1.1.1 The PES principle

An analysis of a PES project should reasonably offer a clear idea of what a PES project is. Nevertheless, the previous literature has not always been able to produce a clear distinction from other approaches to conservation. In the aftermath of the Brundtland Report (Brundtland 1987) and the Rio 1992 conference, conservation approaches increasingly incorporated a dualistic approach stressing that alleviating poverty was the only way to protect the environment (Wunder 2005). Integrated conservation and development projects (ICDPs) and Sustainable Forest Management (SFM) were the most prominent instruments of this new era of conservation projects, although titles vary and clear definitions are often lacking (Ferraro and Simpson 2002:340; Wunder 2005).

Even though ICDPs and SFM projects have had scattered successes, they have not provided major shifts in tropical land-use trends. Furthermore, the positive feedback link between conservation and poverty alleviation was criticized since trade-offs seemed as likely as synergies. There was a rising need for a new conservation paradigm with more focus on more direct conservation approaches and the PES principle has risen as a promising tool for conservation. Since the PES principle is based on compensation to landowners for their incurred costs of conservation, the PES principle acknowledges that environmental management do not offer win-win situations in every context. On the contrary there may be trade-offs and conflicts of interest in land use management that may be resolved through compensation (Wunder 2005).

Wunder (2005) offers one of the most cited definitions in his 5 criteria for the PES principle. PES is (1) a voluntary transaction in which (2) a well-defined environmental service (or land-use likely to secure that service) (3) is bought by at least one user (4) from at least one provider (5) if the provider continuously secures the provision of the service (conditionality). However, there are many PES schemes that do not fulfil all these criteria. Wunder (2007) thus makes a distinction between genuine and "PES-like" schemes. This could be problematic, since a "definition that excludes the bulk of PES cases can be deemed at least flawed" (Muradian, Corbera et al. 2010).

PES is often compared to ICDPs, but a fuller understanding of its features can be obtained by putting it in relation to all the conservationist's available policy instruments. Figure 1 below from Wunder (2005:6) presents the PES concept in relation to other policy instruments according to the degree they rely on economic incentives and to the extent to which conservation and development is bundled together.

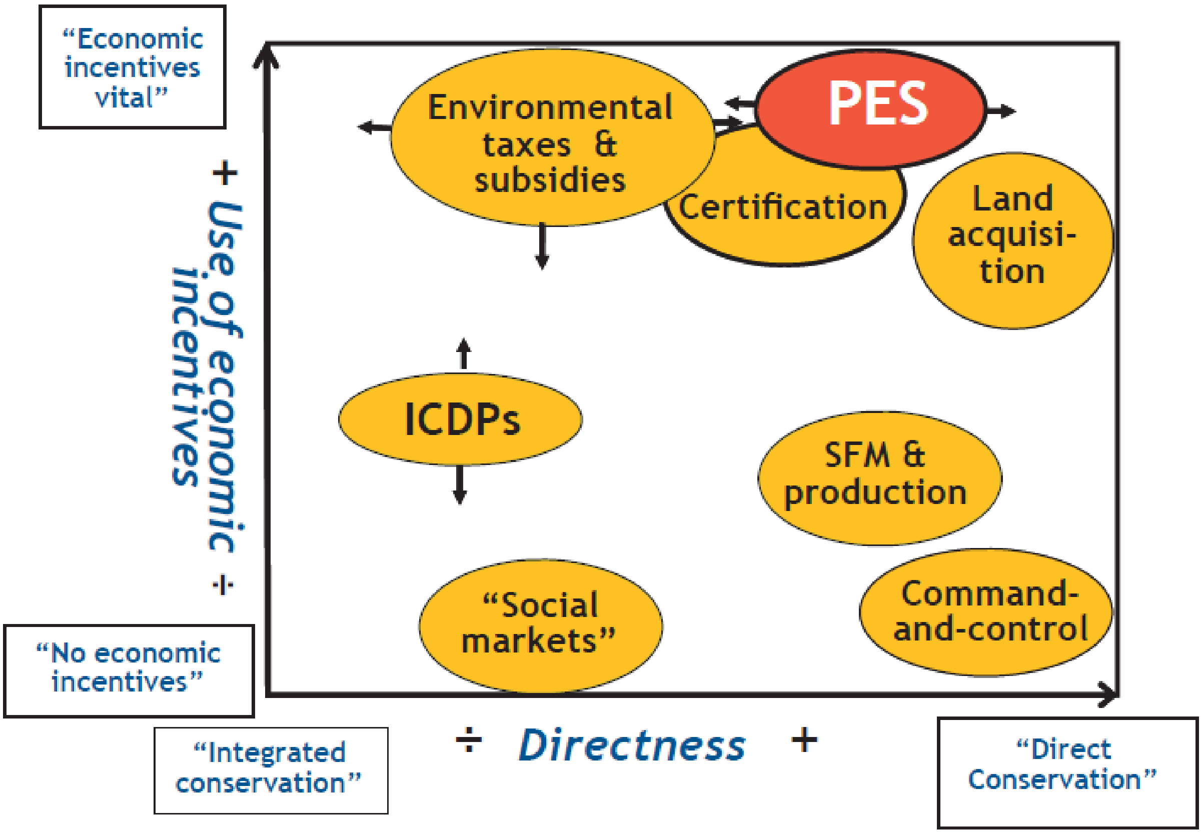

Figure 1. Comparing PES to other conservation approaches (Wunder 2005:6)

The interested reader may refer to Wunder (2005) as a commencing point to more detailed description of each policy instrument in the figure above. Nevertheless it is apparent that PES is categorized by a pronounced use of economic incentives, similar to environmental taxes and subsidies. However, the PES approach is more direct since taxes and subsidies are aimed at broader resource-use patterns. Command-and-control regulation is often criticized for being inefficient as it tends to prescribe the same level of activity to all providers of environmental services, irrespectively of the costs incurred or benefits provided. The market aspect of PES allows it to seek out areas of higher value where services can be supplied at a lower cost. Finally, ICDPs have often provided incentives to participants upfront in the hope that participants might later change their behaviour. PES improves this situation by compensating conservation behaviour directly and conditional upon service delivery (Engel, Pagiola et al. 2008:668-670).

Although PES is sometimes presented as a substitute for command-and-control measures, it is just one of many potential tools at hand for conservation planners, and can often accompany other methods. Wunder and Albán (2008) studied a PES project in northern Ecuador which complemented a defunct forest law and found that the mere threat of stricter law enforcement following the enactment of the PES project, kept payment rates low, hence increasing efficiency.

1.1.2 Theory underlying compensation in a PES scheme

The theoretical basis for PES as an economic instrument to manage environmental externalities was developed long ago, starting with Pigou's theory of potential market failures when externalities are present (Costa and Zeller 2003) and continuing with the Coase theorem (Coase 1960). In a free market with clearly established property rights and no transaction costs, the initial endowment of property rights makes no difference to efficiency. The polluter-pays principle often embraced in environmental management is thus not a necessary condition for achieving efficiency. PES schemes should fulfil the following two conditions to be efficient: (i) the compensation should at least be equal to the *opportunity cost* of providing the environmental service; and (ii) the level of the compensation should be equal to or lower than the value of the environmental service (Kosoy, Martinez-Tuna et al. 2007).

Conservation programmes require that people change resource-use patterns and therefore incur an opportunity cost. As conservation increasingly relies on incentive-based approaches such as PES, a solid understanding of the concept of opportunity costs is crucial for setting appropriate payment levels to compensate private landowners for their incurred costs. Since even well-trained economists can have an insufficient understanding of opportunity costs (Ferraro and Taylor 2005), a clarification may be at place. The principal question is thus: what level and kind of benefits or compensation will instigate participation by individuals who control the natural resource? Or, "what incentives are needed to offset the opportunity cost of conservation faced by the resource owner?" (Niesten and Zurita n.d.).

The following example from Niesten and Zurita (n.d.) may clarify the concept:

> "In Guyana, Conservation International (CI) is the holder of a 'conservation concession,' essentially a conservation incentive agreement between CI and the government (Hardner and Rice, 2002). This agreement follows the model of a timber lease, under which CI pays to the government of Guyana an amount based on what the government would have obtained from issuing a timber concession, but the lease agreement explicitly notes the intent to manage the area for biodiversity conservation rather than commercial harvests. Thus, in negotiating the lease terms, CI and the Guyana Forest Commission considered the opportunity cost of conservation faced by the government – principally, the revenues forgone by not logging the area."

The above example provides a rather simple scenario since it only incorporates the financial flows. Opportunity costs can also comprise of environmental externalities, cultural and spiritual values to a local community of cultivating their lands or conserving nature. If these values are incorporated, the resulting opportunity cost may be either higher or lower than the strictly financial opportunity costs. For a farmer faced with the decision to enrol some parcels of his land in a PES-scheme, conservation of neighbouring plots may reduce the environmental damage or increase water supply, and thereby increase the productivity of another field. These questions and unclear causal processes complicate the assessment of the relevant opportunity cost of conservation.

Coasean theory stipulate that by providing a performance based reward for conservation measures, landowners will consider the externalities of their land use (price effect) (Kosoy, Martinez-Tuna et al. 2007). However, influenced by psychological theory of intrinsic motivations, *Motivation Crowding Theory* suggest that providing extrinsic incentives (e.g. monetary rewards or punishments) can both undermine or strengthen individuals intrinsic motivations for conservation (Frey and Jegen 2001), such as a community's self-interest and pride in forest conservation (Deci et al. 1999 cited in Wunder 2007). If compensations are perceived as supportive they could *crowd in* intrinsic motivations and reinforce good environmental stewardship (crowding-in effect). However, if regulations are perceived as increased top-down control from the state, payments may *crowd out* intrinsic motivations (crowding-out effect) (Frey and Jegen 2001). Implementing PES projects could thus reduce the conservation effort (Wunder 2007).

Cardenas et al. (2000) applied the Motivation Crowding Theory to a study on local environmental policies in three rural villages in Colombia. Their result may be troublesome for small-scale environmental projects in the region, since they found that well-intentioned but modestly enforced local environmental policies, predicted by standard theory to improve overall welfare, may "do more harm than good because their existence triggers the crowding-out of socially desirable behavior" (Cardenas, Stranlund et al. 2000:1731). However, the regulation applied in their study is characterised by top-down control, while many PES schemes are perceived by participants as support for implementing socially desirable activities (e.g. Kosoy, Martinez-Tuna et al. 2007:452) and are thus more likely to generate a crowd-in effect.

PES projects implemented where previous policy instruments, e.g. command-and-control, have failed may also create perverse incentives. If policy makers starts paying people to obey the law in areas where most landowners already comply with the legislation, perverse incentives are created to cease doing so in order to receive payments (Wunder and Albán 2008).

1.1.3 Targeting

The current literature in environmental economics and conservation biology stress the importance of integrating cost considerations early in the planning process to optimise the level of conservation for a fixed budget (Naidoo, Balmford et al. 2006). However, even if costs are acknowledged as a targeting criteria, it is not implemented in most PES schemes (Wünscher, Engel et al. 2008). Estimating the opportunity costs is important for providing a solid framework for setting suitable payment levels. This will affect which plots and how many that will be enrolled in the conservation program. Knowledge of how opportunity costs differ in the landscape is crucial if one wants to maximise the conservation effort with limited funds.

PES programs are often characterised by voluntary participation of service providers. This may become a problem when applicants hold land that adds little to the service provision levels. Selecting those service providers that can offer additional service provision may increase program efficiency considerably. Three criteria for targeting as identified by Wüscher et al (2008:822) are (i) the level of environmental service provision, (ii) risk of environmental service loss, and (iii) landowner's cost of participation[1]. In their study, Wünscher et al. (2008) conclude that of these three criteria, participation costs was the most important variable for boosting efficiency in their case.

Targeting service providers that offer high additional service provision may be combined with differentiated payments, i.e. appropriating the payment level individually to each service provider. By paying low-cost landowners less, buyers of environmental services free up resources that can be used to pay high-cost landowners who may provide higher levels of additional environmental services (Ferraro 2008). However, several authors emphasize that setting differentiated payment levels may be politically unfeasible (Wünscher, Engel et al. 2008) as providers of environmental

[1] Participation cost is defined by Wünscher et al (2008:822) as the "sum of opportunity, transaction, and protection costs, which jointly determine the minimum payment required for the landowner to participate".

services may regard differentiated payments as unfair (Ferraro 2008:816; Muñoz-Piña, Guevara et al. 2008:729) and could worsen social conflicts and jeopardize the trust between policy makers and service providers. A way around this problem is offered by Wünscher et al. (2008:831), who suggested that auctioning out conservation contracts is a "powerful way of making payment differentiation politically acceptable, because service sellers suggest the price themselves".

1.2 PES projects in the region

Even if the theoretical framework of PES was developed long ago, the practical implementation in developing countries have started to emerge only during the last two decades (Landell-Mills and Porras 2002; Rosa, Kandel et al. 2004; Dillaha, Ferraro et al. 2008). Latin America is the most prominent region with PES projects at all scales, ranging from small projects in Colombia (Borda Almanza, Moreno-Sánchez et al. 2009; Garzón 2009), Bolivia (Robertson and Wunder 2005; Asquith, Vargas et al. 2008), Ecuador (Wunder and Albán 2008) to national PES schemes in Mexico (Kosoy, Corbera et al. 2008) and Costa Rica (Pagiola 2008).

Colombia has developed several creative mechanisms for financing conservation and charging users of environmental services. One example is the PES-like project in the Cauca Valley, where voluntary fees are collected from downstream associations of water users to protect forest and vegetation cover in upstream highlands to increase water flows and stabilise discharges (Echavarría 2002). However, many projects do not fulfil one or more of the 5 criteria for a PES project as listed above, e.g. by not properly defining or measuring the environmental service or have lax or unclear conditionality (Blanco 2007). Numerous advanced PES projects are in development (Garzón 2009) and "a national PES strategy is being prepared that may well give Colombia a leading role in PES implementation in the region" (Dillaha, Ferraro et al. 2008).

The threat of water shortages is becoming increasingly acknowledged in Colombia and environmental planners are experimenting with new progressive policy instruments in several locations to tackle problems with water quality and quantity. The surroundings of the colonial town Villa de Leyva in the eastern mountain range of Colombia represents one of these sites that have turned into a hotspot for PES projects. Several successful projects, albeit small in size, have been running for a few years. In 2006 a pilot PES project was implemented in the micro-watershed Chaina, a tributary to the Cane-Iguaque river basin, and supplier of water to five water supply systems in Villa de Leyva. This project included a compensatory mechanism to encourage conservation and changes in private land-use to reduce water sedimentation and improve seasonal water flow regulation (Borda Almanza, Moreno-Sánchez et al. 2009). This pilot created the basis for adapting a local PES scheme to an extended regional program, involving a greater number of users and beneficiaries, and involving institutional actors such as municipal mayors of Chíquiza and Villa de Leyva.

1.2.1 Study area – Background of the Campohermoso project

The study area is defined as the watershed of Campohermoso, which encompass an area of 7459 hectares and is located in the municipality of Chíquiza in the Department of Boyacá. The area is characterised by its mountainous landscape and resulting cold climate; the watershed is situated between 2800 to 3750 meters above the sea level and 75.21% of the area has a slope between 12% and 50%. A part of the watershed is located in the neighbouring national park, *Parque Natural Nacional Santuario de Flora y Fauna de Iguaque* (Borda Almanza 2010). The watershed is strategic not only for supplying drinking water to 12 835 inhabitants in the Municipalities of Villa de Leyva and

Chíquiza (DANE 2005), but also for conserving biodiversity as it maintains important ecosystems which constitute the habitat for at least 135 plants, 155 insects and 30 bird species (Borda Almanza, Moreno-Sánchez et al. 2009; Moreno Sánchez, Maldonado et al. 2009). The location of the study area is presented in Figure 2 below.

Figure 2. Location of the Campohermoso Watershed (Google Maps 2010)

Cultivation of potatoes in the Campohermoso watershed, a tributary of the greater Cane-Iguaque river basin, grew rapidly from the late 1950s and onwards. New varieties of potatoes were introduced and traditional agricultural practices like organic fertilizers made of sawdust and manure were abandoned. Large landowners introduced the use of synthetic substances which have since become popular among the whole farming community. A growing population and fragmentation of farms accelerated the transformation of the landscape from forest and wetlands to potato monoculture, with significant changes in downstream water quality and water supply. The intensive land-use in the cultivation of potatoes and the absence of soil conservation practices has lead to severe erosion and loss of topsoil horizon (Borda Almanza 2010).

The decreasing supply of environmental goods and services from the basin contrast sharply with the increasing demand for water by the municipalities of Chíquiza and neighbouring Villa de Leyva. While tourism and the provision of hotels and restaurants is the main economic activity in Villa de Leyva, the municipality of Chíquiza's main economic activity is the cultivation and sale of potatoes. Both municipalities' populations grow at high rates with an increasing demand for water. The urban and rural population is facing a risk of water supply shortage due to the region's insufficient regulation of their water systems and the degradation of ecosystem services has become a severe threat to the future growth of the region (Borda Almanza 2010).

Tenure is secure in Chíquiza and the predominating tenure form is private property. Land ownership is attained through heritance or purchase, but land may also be leased or pawned. Small farmers may cultivate land on other properties by depositing a pawn as a security to the owner. These contracts usually run for one or two years, and at the end of the period the deposit is returned in its entirety. Approximately 22% of the households cultivate leased or pawned land. The principal commercial produce is potato, combined with cultivation of corn, turnip, fava beans, wheat, oat, peas, onion and carrots. Most farms also own pasture and possess a few cows, sheep, pigs and hens. The watershed consists of 1223 farms ranging in size between 1 to 700 hectares, with an average size of 6 hectares. There is a clear dominance of smallholdings with sizes less than 5 hectares (888 farms, 72%) (Borda Almanza 2010).

The PES program in the Campohermoso watershed is designed to compensate farmers for providing a number of environmental services, including hydrological regulation, increased water supply and reduce sedimentation. By providing an economic incentive the PES program seeks to motivate farmers to make voluntary changes in their land use. The specific interventions to be compensated are yet to be determined, but potential actions include:

- converting to more environmentally friendly practices to cultivate potatoes;
- protection of remnant natural forest;
- creating biological corridors by establishing conservation buffer zones within 25 meters of streams and rivers.

The level of the payment is to be determined in negotiation between the concerned parties. In the planning process of the PES project, a minor opportunity cost study sampled 34 properties in the Campohermoso watershed and used a cost-flow model to estimate the opportunity cost of conservation for potato producers. They found that if the potato producer is to be convinced to abandon potato production and devote his land to conservation, the farmer needs to be compensated with US$653 per hectare per year (Borda Almanza 2010:39).

Previous comparable PES projects in the region have been financed through additional fees on downstream household's water consumption, mediated by one public water service company and several rural water user associations (varying in size from 54 to 2019 users). The PES scheme in Campohermoso is likely to be funded in a similar way, but since the project terms are still under negotiation the contribution of each operator is yet to be determined.

Section 2

2.1 Research Objective

This paper analyses the prospects of creating a PES scheme in the Campohermoso watershed in the Departament of Boyacá. Utilising a geospatial econometric model to map opportunity cost of land conservation, the farmers differentiated opportunity cost of conservation can be predicted across the region using land characteristics and economic variables as independent variables to explain spatially differentiated opportunity costs.

The objective of this report is two-fold. The first objective is to find the *determinants* of opportunity costs among variables for *plot characteristics* such as biophysical and agro-climatic variables, and market variables such as distance to roads and rivers as a proxy for transportation costs. The second objective is to explore how *differences* in opportunity costs of alternative land uses are *distributed* over the region among small-farmers for supplying environmental services in the Campohermoso watershed.

An opportunity cost map of the smallholder agriculture in the Campohermoso watershed is generated that will allow conservation practitioners to understand how opportunity costs differ over the region, and how high opportunity cost areas are distributed in relation to areas with high erosion. Thus, the map can be used by conservation planners to direct payments where they get the most 'bang for the buck', by negotiating with those private landowners who own high priority areas, e.g. areas with high erosion or proximity to rivers. The map can also be used at a later stage in program evaluation to determine if landowners' opportunity costs are fully compensated.

2.3 Methodology

Acknowledging the difficulties in estimating the true opportunity cost (e.g. incorporating different types of non-monetary values as discussed above), this study follows Hoffman (2009) and utilizes a simple methodology based on hedonic price modelling in combination with Geographic Information Systems (GIS) data that permits inferring land values for all land plots in the study area based on land characteristics.

The hedonic land value model used here stems from a Ricardian approach as in Mendelsohn et al. (1994), where the opportunity value of land reflects its highest-value use. If no other alternative land uses exists aside from agriculture, the net rent is exclusively influenced by variables affecting agricultural production. According to hedonic demand theory, land value is revealed through its constituent characteristics. Using a hedonic regression, the contribution of each characteristic to the land value is revealed. Land value can therefore be seen as a function of climate (e.g. precipitation and temperature) and land properties (slope and soil type). Infrastructure and proximity to markets also influence land prices by affecting the cost of transporting production inputs and outputs. Hence a distance variable is included that measure distance to roads (Chomitz, Alger et al. 2005; Naidoo and Adamowicz 2006). Land cover choice can be viewed as an endogenous consequence of agro-climate and market access (Chomitz and Gray 1996) and therefore serve as a proxy for unobserved spatial characteristics (Chomitz, Alger et al. 2005). Various capital improvements, such as terracing or planting of perennials, can also affect land values. However, no significant capital improvements in agriculture could be encountered in the region and hence left out of the model.

As has been discussed above, the value a farmer assigns his land may or may not be limited to its value as a production input to agriculture. Land that has been cultivated by ancestors for several generations may have a higher cultural or spiritual value to the lands tenant. Acknowledging that these sentiments are hard to quantify, social characteristics, such as age, sex and the numbers of years the respondent had been cultivating the land, are included as a rough proxy for these characteristics. The resulting regression takes a step away from hedonic theory as it does no longer model market prices for properties or revealed preferences in actual market transactions, but the subjective value respondent attributes their land.

Land values can thus be expressed as a quasi-hedonic function of environmental, spatial and socio-economic characteristics. Data of environmental variables and distances is available for all properties throughout the region; property specific social characteristics are only available for respondents, but census data provide population averages for the whole municipality. Thus, if social characteristics are not found to affect respondent's stated property value a representative sample can be used to predict land values across the study region. Although this is also the goal of my thesis, social characteristics of respondents were gathered to verify if they are indeed significant and if so region average should be included for extrapolation of the results. Land values are modelled as:

$$\Pi_i = \beta_0 + \beta_1 E_i + \beta_2 D_i + \beta_3 X_i + \varepsilon_i$$

where Π_i is the land value in US dollars of the *i*th farm (i=1, ...n), E_i is a vector of environmental variables, D_i is a vector for spatial variables (e.g. distance to roads and nearest water source) and X_i is a vector for other variables including farm size and socioeconomic characteristics of the respondent.

There are four land value candidates for the regressand; stated value of property; stated and observed rental value; observed sale value; and observed value of deposit in pawn.

2.3.1 Limitations, assumptions and other caveats

During the process of finding a suitable methodology for my analysis it was found that farmers frequently rented or pawned land. A previous minor study of the opportunity costs of conservation among 34 farms in three settlements of Chíquiza, found that 17% of the properties were either leased or pawned. Since local land markets were functioning well it is assumed that farmers are well aware of the value of their property.

It is assumed that the four proxy variables applied to the respondents reveal information that can be used to estimate the opportunity cost of setting aside land for conservation. The PES scheme in the Campohermoso watershed may also compensate landholders for applying better environmental practices. In that case, there is another type of cost, namely the cost of adopting better environmental practices (e.g. acquiring and planting of green manure, and technical assistance). On the other side, there are also savings generated by reduced use of agrochemicals, and increased revenues since farm yields may rise as erosion decrease and soil quality increase (Borda Almanza 2010:41). The best way to estimate the opportunity cost in this situation would be to compare the economic performance before and after the implementation of these altered agricultural practices. The time frame of this thesis did not allow for this. It is assumed that the existing proxies reveal the *spatially differentiated distribution* of the cost of applying better environmental practices, but not its precise *levels*.

The limitations of using land values as a proxy for opportunity costs has already been noted several times above. Other authors have proposed that land values serve as an upper bound on opportunity costs of dedicating a property to conservation if owners incur benefits from standing forests (Chomitz, Alger et al. 2005). "This is an upper bound because it assumes that conservation entails forfeiting all future streams of income and nonmarket benefits associated with the property. However, landowners may derive benefits from ownership even when the property is maintained in a forested state". This includes non-timber forest products and environmental services such as regulation of water quantity and quality. The methodology in this paper extends this line of thought by allowing farmers to state their perceived values of their properties, which may differ from the commercial value of the property. The true opportunity cost that incorporates not only the financial value of the plots, but also different sentiments to land, may be higher than calculating the discounted flow of future net benefits.

2.4 Data

To present the spatial variation of opportunity costs in the Campohermoso watershed, ecological and economic modelling is integrated, and environmental endowments of land are viewed as production inputs. The methodology relies on two main data inputs:

- Georeferenced stated and observed value and rental value for properties.
- Continuous geospatial data for biophysical and agro-climatic variables, and maps of roads and rivers in the study region.

2.4.1 Property value survey

Land values were collected during June 2010 through an in-person survey of farmers in the Campohermoso watershed. An English translation of the survey can be found in the appendix. 114 individuals owning, renting (9.91%) or possessing land were surveyed concerning land use, values of properties and personal characteristics. However, three surveys were not used for econometric modelling, due to missing data. Of the 111 remaining surveys 9.91% were renting land, 89.19% owned their properties and 14.41% properties had parts pawned.

Several persons with knowledge about the local land markets in the area were consulted in developing the questionnaire, including the Asociación de papacultores la San Pedrana[2], employees at Patrimonio Natural[3], personnel at the neighbouring Santuario de Fauna y Flora Iguaque[4] and local farmers. The survey was adapted continually during this process and emphasis was placed on land values.

Three different forms of tenure are present in the region. A property may be owned, when the owner possess formal papers documenting his or her ownership of the property. Land transactions between two nonrelated parties were common and effectively transfer the property ownership. A property may also be owned without possessing the formal documents when the property has been passed through generations. Both these forms of ownership are considered secure and no distinction is made in this paper between these two types of ownership.

A property or part of a property may also be rented. None of the encountered rental arrangements had any final expire date and rents were usually paid annually. Farmers can also possess land by depositing a pawn for the land to the owner. These contracts usually run for 1 or two years, and the deposit was later returned in its entirety to the tenant.

Respondents owning land were asked for actual sale price at the time of acquisition, estimated rental value of their parcels were they to lease their land and the total value they perceive of their properties. Respondents renting land were asked for the actual rental price and their perceived total

[2] A local collective of potato growers
[3] Environmental fund for biodiversity and protected areas created by the Colombian Ministry of the Environment, Housing and Regional Development
[4] Neighbouring national park to the west of the study area

value of the plot. Respondents cultivating land for which a pawn had been deposited were asked for their perceived total value and rental value.

Many respondents were at first reluctant to place a value on their land, as they had not and would not sell or rent any land. Only after ensuring that their response would not be used by authorities for tax purposes or the like, were they willing to state a value of their land. It is assumed that these values at least partially incorporate other non-monetary values such as their sentiments for their land.

Each farm who participated in the survey was geo-referenced using a geospatial positioning system (GPS). The selection of farms to be included in the survey was dependent on encountering the owner or tenant on the property. Therefore, almost all of the surveys were carried out on properties which included the house of the owner or tenant. This is also the reason, combined with time constraints, why random sampling was not applied. Sample selection was guided by obtaining a representative sample of each village's different landscapes and slopes of land. Steep areas are to a high degree located inside the neighbouring National Park, where there are no properties that could be surveyed. Thus, the sample has a higher frequency of more level areas. The location and size of the surveyed properties are presented in Figure 3 in relation to the slope of land, and in Figure 4 in relation to the terrain. The survey represents approximately 9% of the sampling frame.

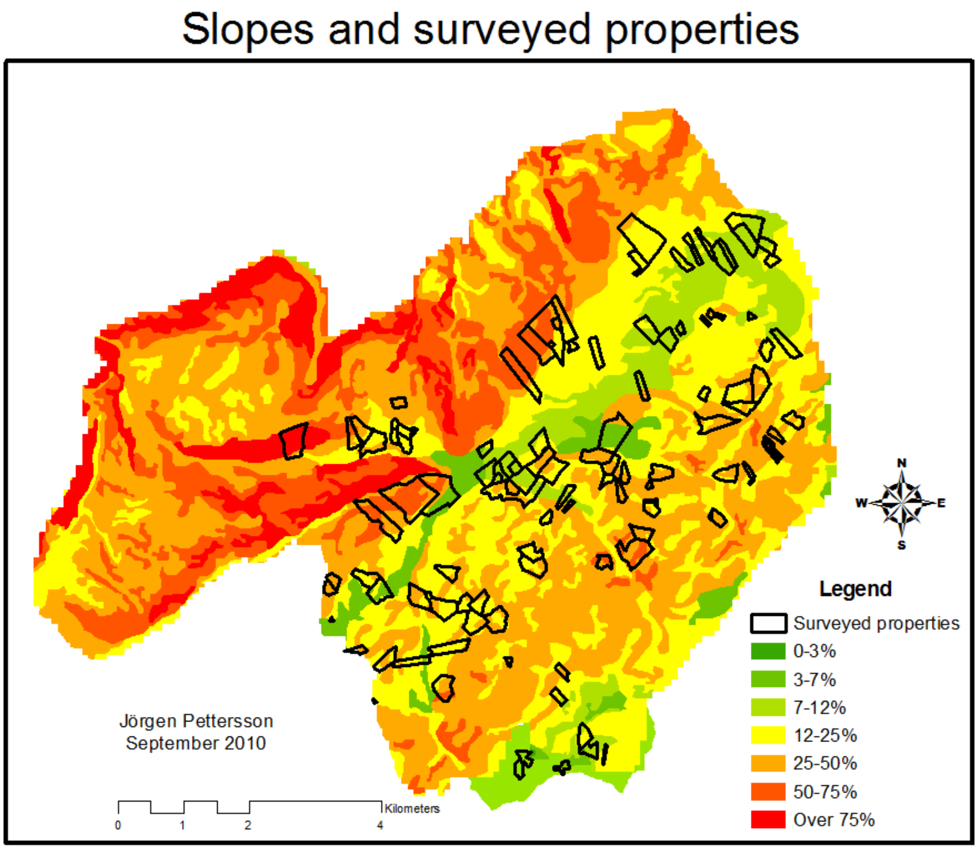

Figure 3. Surveyed farms in relation to the slope of the land in the Campohermoso watershed

2.4.2 Biophysical variables

The spatial data used for analysis was obtained from Instituto Geografico Augustin Codazzi (IGAC), who compiled data from a number of sources. The resolution of the GIS data varies and was available at a 90 by 90 meter resolution or better. GPS coordinates and altitude were taken at the centre of each surveyed property, and the land characteristics of that point were then used for the whole property. Where applicable the pre-existing data were complemented with observations from the property value survey. The data is outlined below. For more information please refer to the original source, *Capitulo 5: Metodologia y resultados del componente biofísico*.

Land cover: Land cover data used in the regression analysis were obtained from the property survey. A dummy variable equal to one was created to depict a property where more than 50% of the property was forested. Forest is likely to be found on marginal lands of little use in agricultural production; the value of the land is thus expected to be lower. For extrapolation of the regression results to the whole study region, data for the whole study region was available from IGAC, and differentiating between 12 different types of land-cover. For the purpose of this study, three categories were merged to form the category forest[5]: shrubland, moderately intervened natural forest, and heavily intervened natural forest. Again, a dummy variable depicting forested property was created, equal to one if forest covered more than 50% of the property. This data was used for extrapolation of the regression result.

Slope: The slope map was produced by information from the Shuttle Radar Topography Mission project (SRTM), with an accuracy of 30m. Slopes were classified into 7 different categories: 0-3, 3-7, 7-12, 12-25, 25-50, over 50 degrees. These category values were normalised by taking the natural log of each category's mean. More level areas are expected to be of higher value to the farmer. The distribution of slopes in the Campohermoso area is presented in Figure 3 above.

Altitude: A topographic map was obtained from IGAC to enable extrapolation of regression results. The altitude at each surveyed farm was noted using GPS. The natural log of altitude was used in the regression analysis. Higher altitudes imply harsher conditions for cultivating crops and is thus expected to be associated with lower land values.

Climate: The Caldas-Lang model was applied for the climatic classification of the Campohermoso basin. This model combines the works of Caldas and Lang to obtain 25 mathematically defined climate types. The climate classes accounts for mean annual temperature and average annual precipitation. Four climate categories are found in the study area. However, one climate category is almost entirely restricted to the extreme altitudes in the neighbouring national park, hence no farms could be interviewed belonging to this category. The three remaining climate categories are: Cold, humid climate; Very cold and cold, humid climate; Very cold, humid climate. However, due to the few observations made in the last climate category (8) it was merged with the intermediate category. Hence, two broad climate categories are used in the regression analysis. A colder climate limits agricultural production and hence decreases the property value.

Land relief: The different types of terrain are the result of several geological processes, and determine the formation and evolution of soil, condition the type of natural vegetation and restrict the ability of cultivating the land. The terrain map was based on a soil survey by the Boyacá

[5] The table in the appendix outline how the reclassification of land cover was made.

Department at 1: 100 000, and LANDSAT satellite image 856 of 2000. The terrain is divided into 4 categories, ordered below by their expected contribution to land values starting with the least valuable:

- *R1* constitutes of high peaks and very steep slopes (over 25%). The soil is either (1) sandy, moderately drained with shallow pedological development, or (2) formed of volcanic ash on sedimentary rocks.
- *R2* constitutes of erosional or depositional pediment (glacis), a surface thinly covered with volcanic ash on sedimentary rocks and glaciofluvial gravel that has developed at the foot of mountains. Slopes are between 25% and 50%.
- *R3* constitutes of moderate slopes (12-50%), hills and glacis, is located in the central part of the watershed, formed of sedimentary rocks mixed with volcanic ash.
- *R4* is restricted to a small level area in the river valley and slopes are lower than 25%. The soil is formed of colluvial deposits (loose sediment) at the foot of steep slopes and cliffs.

How the terrain differs throughout the study region is presented below in Figure 4, in relation to surveyed farms.

2.4.4 Spatial variables

Maps of the region's road infrastructure and hydrology were obtained from IGAC. As described above one set of GPS coordinates were taken at each observed farm and then used to measure distances from roads and streams. The spatial variables used in the model include the distance from the observed farm to: (1) the Pan-American Highway 45; and (2) distance to the primarily used ("main") gravel road leading from the Pan-American Highway 45 to the population centre of San Pedro. The location of roads in relation to the surveyed farms is presented in Figure 4 below.

Easy access to roads should lower transportation costs to and from the farm. Since the area has a well developed gravel road infrastructure, the difference between properties in the distance to a transportable road is not large enough to justify a limitation to production to the degree that it would affect property values. However, the paved road Pan-American Highway 45 is the main road passing closely to the northeast of the study area and the main route for transportation of goods to the closest market, the city of Tunja, for sale of produced goods. This is also where many farmers buy their inputs to production, e.g. fertilizers and pesticides. It is expected that the further away a farm is located from the Pan-America Highway 45 the lower the property value.

The 'main' gravel road going from the Pan-American Highway 45 and San Pedro is the most trafficked road in the study area and is also the route of the *collectivo*, the public bus, to the large city of Tunja. Farmers may use the public bus for transportation of small quantities of inputs or outputs to production or to attend marketplaces nearby. It may also be easier for a farm close to this road to organize transport for their goods and they may face lower transportation cost. Therefore, it is expected that as the distance to this road increases the lower the property value.

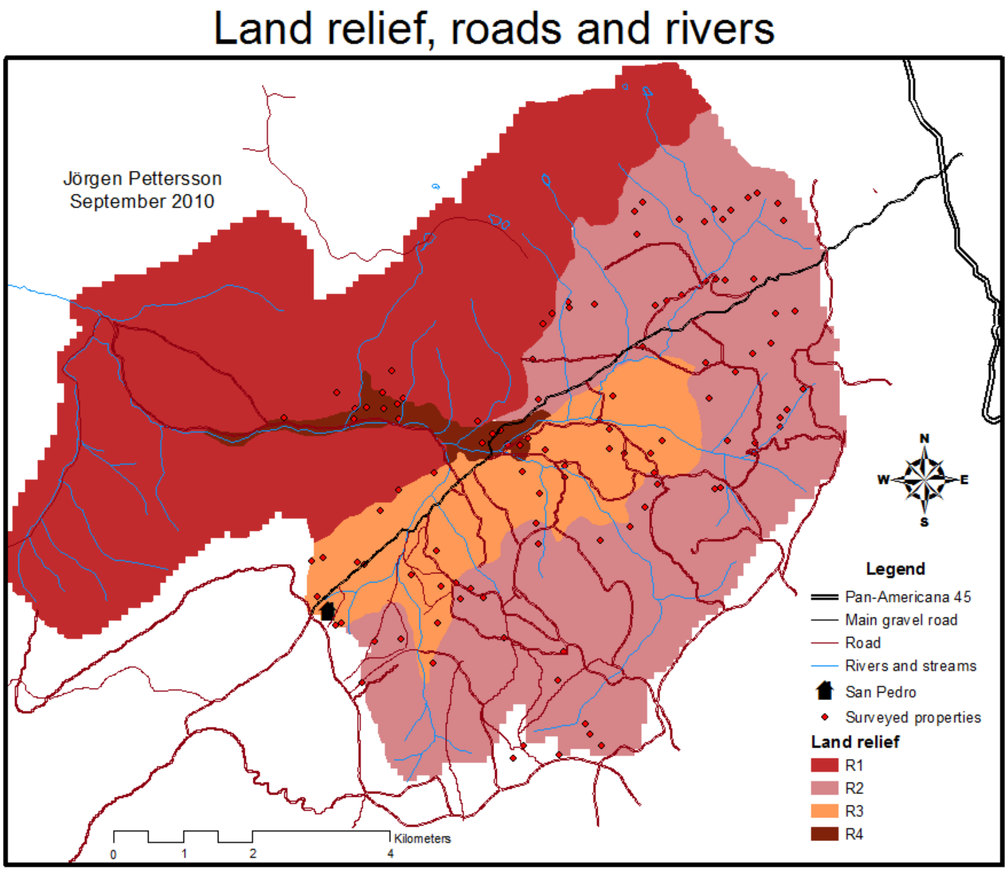

Figure 4. Locations of surveyed farms in relation to land relief categories, roads and rivers.

The survey included questions about the distance between the observed farm and the nearest river or stream and the distance to the Pan-American Highway 45. Both the distance in kilometres and the time needed to walk to the said point were asked. However, respondent had severe difficulties approximating all these distances. Instead, all distances between two points were obtained by using GIS data to measure the distance as a straight line, ignoring the regions topography. The weakness of this method is that the distance measured 'as crows fly' may not accurately portray the actual distance for travelling over land in a mountainous landscape. The purpose of using these distances is to proxy for spatial characteristics due to diversified transportation costs between plots, and while acknowledging the limitations of the method these variables are used in the model as spatial variables.

2.4.5 Other variables

The data for socio-economic characteristics for my sample was collected during the property survey. Survey questions included the respondent's sex, age, years of education, and the number of years the respondent had cultivated the plot in question.

Census data covering the whole region were retrieved from El Departamento Administrativo Nacional de Estadística (DANE). Data from 2005 covered population size, sex and age of inhabitants and number of households (DANE 2005). Years of education of the inhabitants were available from year 2009 (DANE 2009).

The size of each plot was available for the whole study region from IGAC's data over properties' rateable values. Furthermore, the property value survey covered the size of each farm. Although most respondents knew exactly where the border of their property was located, many had a very vague idea of the actual size of the property in fanegadas[6] or hectares. However, all respondents knew how much sacks of potatoes or other crops they had sown. With the help of a number of farmers in the area, a conversion table was constructed to assist in determining a property's size. Most farmers sowed their crops with the same density, but when large irregularities were encountered the conversion table was adopted correspondingly. The conversion table can be found in the appendix.

The tables below presents descriptive statistics for the variables discussed above.

Table 1. Descriptive statistics for continuous variables					
Variable	**Category**	**Mean**	**Std. Dev.**	**Min**	**Max**
Stated total value (USD/ha) n=111	Monetary	11733	12090	122	80526
Stated rental value (USD/yr/ha) n=100	Monetary	877	2280	3.7	20100
Observed rental value (USD/yr/ha) n=11	Monetary	110	106	13.4	349
Observed value of deposit in pawn (USD/ha) n=15	Monetary	1837	1537	519.5	5368
Altitude	Environmental	3049	128	2832	3324
Distance to Pan-American Highway	Spatial	6119	2287	2325	10013
Distance to main gravel road	Spatial	1171	906	0	4145
Age	Socioeconomic	49.56	14.9	18	78
Education (number of years)	Socioeconomic	3.30	2.19	0	11
Years on the property n=110	Socioeconomic	27.5	16.0	0	64
Property size (hectares)	Other	4.49	5.32	.097	40

Note: If not otherwise specified, n=111

[6] 1 fanegada = 0.643 hectares

Table 2. Descriptive Statistics for dummy variables				
Variable	**Characteristic**	**Category**	**Frequency**	**% of Total**
Land cover	Forested property	Environmental	11	9.91%
Slope	3-7	Environmental	3	2.70%
	7-12	Environmental	25	22.52%
	12-25	Environmental	49	44.14%
	25-50	Environmental	34	30.63%
Climate	Cold, humid	Environmental	46	41.44%
	Very cold and cold, humid; and Very cold, humid	Environmental	65	58.56%
Land relief	R1	Environmental	7	6.42%
	R2	Environmental	65	59.63%
	R3	Environmental	25	22.94%
	R4	Environmental	12	11.01%
Sex	Male	Socioeconomic	73	65.77%
	Female	Socioeconomic	38	34.23%

Note: n=111

Section 3

3.1 Results

Linear ordinary least squares regression was used to model property values based on their biophysical attributes, distance to markets and socio-economic characteristics of the respondent. Due to high correlation between the variables altitude and climate, the latter was omitted. Almost everyone interviewed were born in the municipality, often on the same farm, and very few respondents had moved to the region from other municipalities or had lived outside the municipality for considerable time. Furthermore, the younger the respondent the longer they had stayed in school before starting to work on the farm. Correlation was therefore high between age, education and the number of years the respondent had cultivated the plot. Thus, only the variable for age was included in the regression analysis.

Stated total value was the only proxy for opportunity costs that performed satisfactory in the analysis. Rental value or observed sale values did not express any meaningful relationship when regressed on the available independent variables. Using the rental value as the dependent variable produced an extremely low goodness of fit and only one significant variable (forest dummy). Using observed sale values generated a model with slightly higher goodness of fit, but half of the parameters had the opposite sign of what was expected a priori. The number of observations of observed value of deposit in pawn were not sufficient to allow for further modelling.

Since the rental value of a property is the proxy for opportunity cost of conservation that is most similar to the payment method in a PES scheme, it is troubling that using this proxy did not perform well in the regression analysis. One explanation might be that when respondents were asked for a total value of the property, the value of the whole property was taken into account including its forested and non-cultivable parts. The rental market, however, is more closely related to the pawn market. It is relatively common for larger farms to let small-farmers cultivate small parts of their properties in exchange for a pawn in deposit. Respondent may have used this situation as a benchmark to estimate the rental value of a productive area of their property, instead of taking an average of the whole property including its less productive parts. This is understandable, since it's unlikely that someone would be interested in renting uncultivable plots. However, this impedes with the analysis since the environmental data was collected by assuming that the centre of the property would be representative of the whole property. One should also bear in mind that since the rental market is similar to the payment method in a PES scheme, this proxy may accurately describe the farmers' opportunity costs. This implies that the payments in a PES scheme cannot necessarily be guided by the production potential of each property.

The following regression analysis is performed by using the natural logarithm of the total value of the property as given by respondents as the dependant variable. Since three variables were omitted due to collinearity among explanatory variables, I follow Lovell (1983, cited in Gujarati and Porter 2009), in using the *true level of significance*, α', where the nominal significance levels, α, of 1%, 5% and 10% corresponds to the true level of significance of 1.27%, 6.32%, and 12.5%. The model below have a relatively good explanatory power with an R^2 = 0.6201 and $\bar{R}^2$ = 0.5779.

Table 3. Logistic regression model using respondents' stated values of properties to proxy for opportunity cost of conservation in the Campohermoso watershed

Variable	**Coefficient**	**(t-statistic)**
Property size	-0.0903	-6.33***
Altitude	0.00137	1.36
Forested property	-1.40	-5.50***
Natural logarithm of slope	-0.415	-2.96***
Age	-0.000122	-0.02
Dummy for male	0.257	1.63*
Natural logarithm of distance to Pan-American Highway 45	-0.690	-2.97***
Natural logarithm of distance to main gravel road	-0.120	-1.50
Land relief: R1	-0.820	-2.23**
Land relief: R2	-0.610	-1.72*
Land relief: R3	-0.454	-1.52
Constant	14.2	-3.68***
$\boldsymbol{R^2}$ = 0.6201	$\bar{R}^2$ = 0.5779	F = 14.69***

Note: n=111

Significance level: *** α'=1.27% ** α'=6.32% * α'=12.5%

The size of the property is negatively correlated with stated property value per hectare and highly significant. Owners of larger properties often do not maximise the economic potential of every part of their plots, but left areas of their properties uncultivated. If unused parts of the property were found on marginal lands and family labour was already in use elsewhere, it did not add up economically to hire additional labour. Instead, unused plots were sometimes offered to others, in return for a small deposit in pawn, which offered little economic rent to the land owner. To test if the relationship between land values and property size is indeed linear, the regression was tried again with the property size variable substituted by two dummies; one depicting property sizes smaller than 1ha (smallest quintile) and another representing property sizes larger than 6ha (largest quintile). The estimated parameter was positive for the small property dummy and negative for the large property dummy, thus confirming the overall linear relationship.

In addition, many larger properties were encountered on marginal lands close to or in mountainous areas with extreme slopes and poor soil, resulting in lower stated property values. These areas constitute of land that is not suitable for cultivation or pasture and properties in these areas are often forested. The dummy variable for properties where forest dominates has a negative coefficient and is also highly significant. Forest has a considerable effect on land values, since on average a forested property is worth 75% less than properties used in agricultural production.

The opportunity cost to conservation is estimated as the mean value for each property, and as larger farms often included large parts of uncultivable or forested land, productive areas of larger properties are not accurately estimated by the model. The opportunity cost to conservation of a productive area on a large farm is higher than the mean of the whole farm.

Altitude is not significant and has the opposite sign of what was expected. Higher altitude should limit crop growth and affect property values negatively, hence a negative parameter was expected. The slope variable is weakly significant with the expected sign (negative). As the slope increase by 10% the value of the property decrease by 4.15%, since parcels with steep slopes are less apt for cultivation and grazing.

Of the socio-economic variables, the sex of the respondent is weakly significant. On average, male respondents stated a 29% higher value than female respondents. The age of the respondent is not significant, which can be explained in two ways; either (1) non-use values such as spiritual or cultural values do not affect the value of the property, or (2) non-use values are not captured by the age variable. Unfortunately it was not suitable to include both the age and the number of years the respondent had cultivated the plot in the regression due to high collinearity. A different setting where more inhabitants of Chíquiza had originated from outside of the municipality had enabled further analysis of cultural or spiritual values. This study region does, however, not permit such analysis.

The sign on the estimated parameter for the distance from the observed farm to the Pan-American Highway 45 is negative as was expected, and it is also highly significant. The cost of transports increase the further away a property is located from the main road. More exactly, as the distance from the Pan-American Highway 45 increases by 10%, the property value decreases by 6.9%.

The spatial variable measuring the distance to the main gravel road is of less economic significance than the spatial variable discussed in the paragraph above. As the distance to the main gravel road increase by 10%, the property value decrease by 1.2%. However, it should be noted that there is some interaction between the distance to the main gravel road and the slope variable, as the significance and value of the estimated parameters alter each other to some extent. This may be because the stretch of the main gravel road is primarily through a level area in the middle of the study area. The slight collinearity between these variables is problematic and leaves the spatial variable situated just outside the statistical significance.

Three dummy variables are used to differentiate between the 4 different land relief categories, with the terrain expected to suit agricultural needs best as the baseline. Hence, all estimated parameters have the expected sign (negative) and their economic significance is falling in the expected order; the most extreme terrain, *R1*, is estimated to generate 56% lower property values, *R2* 46% lower, and *R3* 36% lower property values than the predominately level valley in the land relief category *R4*.It should however be noted that *R3*, the terrain closest to the baseline, is statistically not different from the baseline.

Furthermore, another possible determinant of property values may be the presence of buildings on the site. However, the sample data provided too little variance, as only 6 properties were observed without a house.

The respondents' mean of stated total values is US$11,733 per hectare. However, the average of the opportunity cost as predicted by the model for all properties in the watershed is lower, US$7,193 per hectare. The sample does not represent the whole study area well, since very few farms were located in the mountainous landscape to the west. On the other hand, where there are no farmers there is no one to compensate for shifting land use. Thus, the mean of all properties from the whole watershed is not as important. Most farmers are located around the main gravel road or further to the east, an area well represented by the sample.

The mean of the stated rental value was US$877 per hectare per year and the respondents' own answers of total value and rental values were used to determine a discount rate of 13%. Using this discount rate the average rental value of US$538 per hectare per year was determined from the model's prediction of total values. This estimated value for the whole region is considerably lower than the respondents' stated rental values (due to the same reasons as for the total value) and also lower than the result of the previous study in the area which estimated opportunity costs to US$653 per hectare per year.

The model above was used to predict values for the whole study area using region wide data available from IGAC. This data included a property map, hence opportunity cost to conservation per hectare per year in the Campohermoso watershed was predicted for each property. The resulting map of opportunity costs is presented in Figure 5 below.

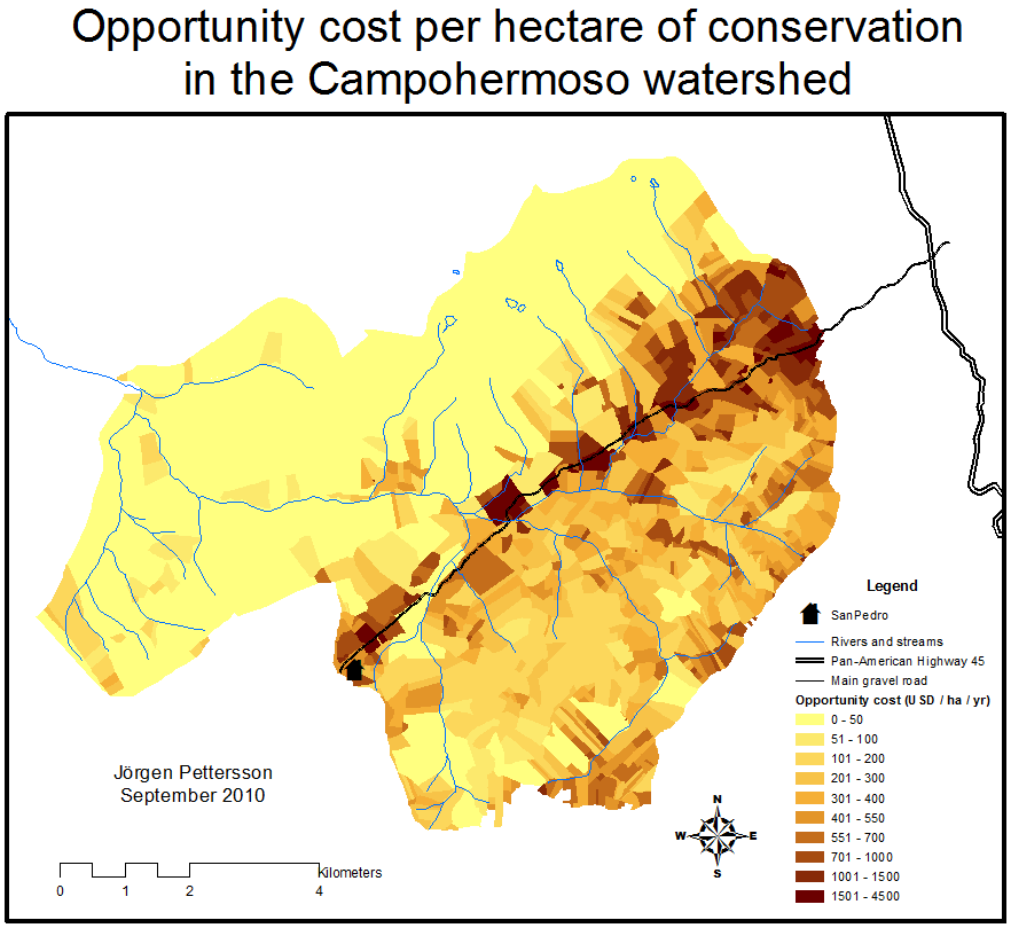

Figure 5. Opportunity cost of conservation in USD per hectare per year for farmers in the Campohermoso Watershed

The opportunity cost map in the figure above shows how the differences in the farmers' opportunity cost to conservation is distributed over the region. It is evident that the opportunity cost varies greatly, with the highest costs in the north-eastern region close to the Pan-American Highway 45, remaining fairly high down along the main gravel road to San Pedro. Furthermore, there is a small level area to the southeast where costs are also fairly high. A significant area in the west carry extremely low opportunity costs below US$50 and an area in the central south with opportunity costs less than US$100. However, one should interpret the map with caution since it is a simplification to present the differences in opportunity costs graphically. It can guide conservation planners to find low-cost service suppliers, but it is not a substitute for knowledge of the region.

In the light of these spatially differentiated opportunity costs, it is interesting to compare opportunity cost levels to the map presenting how erosion levels vary in the area as in Figure 6 below. The erosion data was available from IGAC. Using the Soil and Water Assessment Tool (SWAT), the study region was divided into 38 Hydrologic Response Units (HRUs) based on elevation, slope, aspect and vegetation. Estimated erosion levels are available for each HRU.

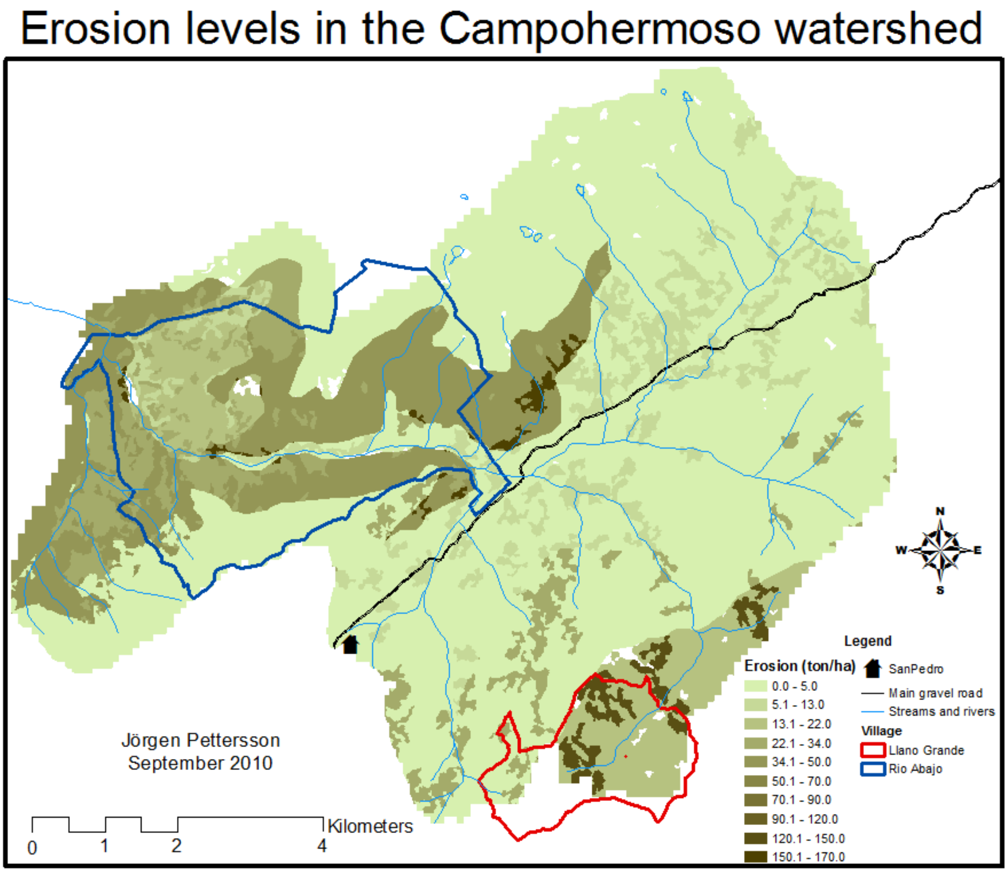

Figure 6. Estimated erosion levels in the Campohermoso watershed

The figure above shows that erosion levels are highest in the western mountainous landscape and in the more level area to the southeast. The two villages where erosion levels are high have been highlighted in the figure above, Llano Grande in red and Rio Abajo in blue. The highly productive agricultural lands of Llano Grande have an opportunity cost to conservation above the median of the study region. On the other hand, respondents in the village of Rio Abajo, a region characterized by its steep slopes on both sides of a river, the predicted average of opportunity cost to conservation for all properties is very low, 72% lower than the region average.

3.2 Discussion

Using data from the Campohermoso watershed, it has been shown that the efficiency of future PES programs can be considerably increased by an initial conservation targeting process incorporating a cost analysis built on spatial data and the inhabitants' own valuation of their properties. The model describing how the opportunity cost to conservation varies in the landscape was constructed using a limited set of geographical data. Due to the small size of the study area some variables correlated, and the possible combinations of environmental variables were few, e.g. the highest altitudes consisted of one single climate, and as altitude decreased the climate changed likewise. A larger study area could have provided larger variation in the data, with more possible combinations of environmental variables.

Socio-economic variables were included in the regression analysis as a crude proxy for sentiments to land that is hard to quantify, e.g. cultural or spiritual values. Since the sex of the respondent was the only socio-economic variable found significant, one can say that the model predicts that men value their land higher in absolute terms, which needs to be differentiated from relative terms. It might be that men value the land higher than women in relation to other goods, but the data does not allow for such an analysis. Furthermore, it is unlikely that the sex of the respondent would be the only determinator of sentiments to land. Rather, one can only conclude that the proxies tried out here was not adequate to catch all the variance. Respondents may still have incorporated such opinions in their answers.

Relating to the three possible conservational actions taken by farmers to be compensated, the results above indicate clearly that the level of the payment should be fairly low for forested properties, as these carry very low opportunity cost (if any at all). The value of a forested property was 75% lower than a non-forested property. However, the exact recommended sum paid for forested plots also depends on other characteristics, e.g. the location of the property in relation to main roads.

It is interesting to note that since the distance to watercourse does not determine the value of a property, creating a buffer zone within 25 meters of flowing water where the land is protected for natural revegetation, can be guided by the same predicted property values as land further away from brooks and rivers. Lastly, the *differences* in opportunity cost to convert to more environmentally friendly agriculture was assumed to be revealed by the method applied in this thesis, but not the precise *levels*. The opportunity cost map presented in Figure 5 above can serve as a guide for conservation planners to target low-cost properties, but the map does not reveal information regarding a suitable level of compensation for this conversion.

Although some authors have reported that differentiated payments may increase conflicts between community members as discussed above, a similar PES project in the neighbouring municipality of Villa de Leyva have successfully come to an agreement individually with each environmental service provider, resulting in variable payments to each provider (Carlos Borda Almanza 2010 *pers. comm.)*. Although the small size (14 providers) of this neighbouring project make it very different in some aspects, it is still compelling to use this minor project for comparing possibilities due to its similarity in service buyers, organisations involved and the close geographic location.

The agriculture production method in the Campohermoso watershed is largely homogenous, intensive and the use of synthetic substances is widespread. Traditional or more environmentally friendly practices are uncommon. Thus, crowding out existing socially desirable land-use behaviour that may result in less erosion and accompanied water sedimentation is not considered to be a significant threat to the success of the future PES project in the Campohermoso watershed. However, continuing developing the PES project in close cooperation with local farmers is strongly advised since active communication at the local level can reduce the tendency of regulations to induce self-interested behaviour.

The methodology employed in this thesis could be applied to other regions designing PES projects, where GIS data is available and the capacity to gather inhabitants' perceptions of the property values is available. The importance of high quality data and knowledge about the agricultural practices of the study region is needed to accurately model economic behaviour. The resulting opportunity cost map should be interpreted with care and it should be kept in mind that it is a simplified presentation of the observable relationship between environmental and spatial characteristics, to opportunity cost of conservation. One should not expect that inhabitants automatically would accept the level of compensation that this modelling exercise has attributed their property. Underneath these broad trends there is considerable variation, which could not be explained by the available data. However, the predicted values can serve as an approximation to guide conservation planners.

3.3 Conclusion

The opportunity cost of conservation for farmers in the Campohermoso watershed was determined to be US$877 per hectare per year on average, as based on the respondents' stated total values. However, it was clear from the regression analysis that opportunity costs to conservation varies between properties and are dependent on the environmental characteristics of the plot, e.g. the slope of the property since more level areas are more productive in agriculture. Also, the distance from the property to important transportation routes are an important determinant of opportunity costs, as longer distance increases the transportation costs of production inputs and outputs. Finally, a smaller property size generate higher per hectare value, thus limiting its possibilities to be set aside for conservation. This is understandable, since smaller plots are often cultivated more intensely, raising the importance of every little area of the plot for the family's sustenance.

The opportunity cost map produced in this thesis may be used as a reference in the upcoming negotiations of setting suitable payment levels to environmental service providers to compensate their opportunity cost. The map demonstrates clearly the variability of opportunity cost of delivering environmental services to downstream benefiters between different property owners in upstream farmers in the Campohermoso watershed.

Furthermore, it was demonstrated that dependent on the specific conservational action taken by the farmer, different payment levels are justified to compensate the farmers opportunity cost. Forested properties had a considerably lower opportunity cost of 75% below non-forested properties used for agriculture. The value of land within 25 meters of watercourse does not differ from land further away from brooks and rivers; hence these landowners do not need to receive a different level of payment to be motivated to set aside land for conservation.

Setting differentiated payment levels in line with the demonstrated variability of opportunity cost may increase the efficiency of the payment scheme. The opportunity cost map can be combined with data over potential environmental service provision. By targeting payments to those areas with potentially high service provision and lower opportunity cost, the total increase in provision of environmental services for a fixed budget can be maximised. However, one should be responsive of the potential mistrust between service providers and environmental planners such a system may trigger. Differentiated payments have been successful in another nearby PES project, where conservation contracts were bilaterally negotiated with each service provider. Auctioning of conservation contracts may also avoid mistrust, since service providers actively suggest the price themselves.

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Appendix 1: Reclassification of Land cover

New classification	Original data
Cropland	Cropland
Pasture	Pasture
Forest	Shrublands Moderately intervened natural forest Heavily intervened natural forest
No observations due to no farms (not applicable)	Rupicolous vegetation Páramo Population centre Body of water
Not in the study area	Forest plantation Uncultivated land Xerophytic vegetation

Appendix 2: Conversion table

	Volume	Volume	Area
Potatoes	1 carga (≈4 bushels)	2 bultos	
	6 cargas		1 fanegada
Corn	1.75 arrobas		1 fanegada (sown with 0.5m between rows)
	1 arroba	4 gallons	
	4 arrobas	1 bulto	

Other conversions		
1 fanegada	0.64 hectares	6400 m^2
1 kg	2 libras (pound)	

Appendix 3: The property survey

(Original version in Spanish available upon request)

No. interview ____________________

Date ____________________ Landscape _________________ Altitude_________________

Interviewer ____________________

Take note of the coordinates of the property: N _______________________ W______________________

PRESENTATION Good morning. We are doing a survey of the habitants of the municipality of Chíquiza with the help of the mayor, the School of El Cerro and the Santuario de Flora y Fauna de Iguaque. The survey is part of a study that seeks to assess the possibility of creating a conservation program for water sources in some villages in this municipality. It is important to inform you that your responses will be treated under strict confidentiality and it will not be possible to associate your name with the information you provide us with. It will take between 15 and 20 minutes of your time to complete. Do you want to help us by answering the questions?

A. Identification and location of the household

1. Name of interviewee		
2. Name of household		
3. Name of village		
4. Sex of respondent	Male	Female
5. Age of respondent		
6. Education of respondent	*(number of years completed)*	
7. For how long have you lived in Chíquiza?		
8. How many persons are there in the household? *Not in the family, but in the household, the persons who stay the majority of their time in the house and normally live in the household.*		
9. How many of these persons work the majority of their time on the farm?		
10. Distance between the property and the nearest river or stream (in minutes on foot and km)	1. min	2. km
11. Distance between the property and the nearest transportable road (in minutes on foot and km)	1. min	2. km
12. Distance between the property and the principal road (in minutes on foot and km)	1. min	2. km

B. Land – Please inform us of the land you use or occupy:

1. Please, we are going to construct a sketch of the property where you will be able to identify the uses.

HAND THE INTERVIEWEE THE PAPER SO HE/SHE CAN DO THE SKETCH

1.1. Read one by one the following items: stream, ditch, body of water, crops, pastures, forests, fallow fields, land unfit for any productive use, roads, houses.

1.2. Upon completion ask where the north or sunrise is.

	Land use	Area	Volume	Productivity
A		fan / ha / %		high / regular / poor / unknown
B		fan / ha / %		high / regular / poor / unknown
C		fan / ha / %		high / regular / poor / unknown
D		fan / ha / %		high / regular / poor / unknown
E		fan / ha / %		high / regular / poor / unknown
F		fan / ha / %		high / regular / poor / unknown
G		fan / ha / %		high / regular / poor / unknown
H		fan / ha / %		high / regular / poor / unknown
I		fan / ha / %		high / regular / poor / unknown

In total: _________

2. Since what year have you been working on the property?	*yyyy*
3. How did you acquire this land? a) occupied by the respondent b) possession or occupation by your ancestors c) bought the land from a third party d) property received as a legacy	other, specify_________________________ ______________________________________ ______________________________________ ______________________________________ ______________________________________
4) How do you describe or qualify the land you occupy / use? a. Individual property → Go to question 5 b. Lease / rent → Go to question 6 c. Pawned/sharecropping/user/in possession/tenant → Go to question 7 d. Other ______________	

No. interview ____________________

5. Individual property

a) What is the area of the property?	fa / ha	
b) If you have purchased the property, in which year did you became the owner of this property?		don't know
c) If you purchased this property, what price did you pay at the time of purchase?	$	per fa / per ha / in total
d) How much do you think your property is worth?	$	per fa / per ha / in total
e) How much would you demand if you were to lease your property?	____________$ per _____ wk/mth/yr	per fa / per ha / in total
f) Do you currently hold any pledged land or lease any area of your property to others for agricultural production or livestock?	Yes → Go to question 8 No → End interview here	

6. Lease / rent

a. Land use (cultivation or pasture)		
b. What is the area of the plot you rent?	________ of _______ fa / ha	
c) How many times each year do you rent this plot for this activity?	________ times per year	
d) If the property is rented, how much are you paying in rent?	____________$ per _____ wk/mth/yr	per fa / per ha / in total
e) If you were to buy the property, how much is it worth?	$	per fa / per ha / in total

End interview here

7. Pawned/sharecropping/user/in possession/tenant ***(Please note the correct answer)***

a. Land use (cultivation or pasture)		
b. What is the area of the plot you possess?		____ of ____ fa / ha
c. How many times each year do you use this plot for this activity?	________ times per year	
d. If you deposited a pawn in deposit, what is the value of the pawn?	____________$	per fa / per ha / in total
e. If you were to buy this plot, how much do you think it is worth?	$	per fa / per ha / in total
f. If you were to rent this plot, how much do you think it is worth?	____________$ per _____ wk/mth/yr	per fa / per ha / in total

End interview here

8. Please inform us of the land you hold pledged or lease:

	1 – leased / pledged	**2 – leased / pledged**	**3 – leased / pledged**
Land use (Cultivation or pasture)			
Area	fa / ha	fa / ha	fa / ha
Productivity	high/regular/poor/unknown	high/regular/poor/unknown	high/regular/poor/unknown
For how much and for how long is the land pledged or lease?	____________$ per _____ wk/mth/yr	____________$ per _____ wk/mth/yr	____________$ per _____ wk/mth/yr
How many times per year?			

No. interview ____________________

Sketch of property
(Question B.1)