CPWF Project Report

Payment for Environmental Services as a Mechanism for Promoting Rural Development in the Upper Watersheds of the Tropics

Project Number 22

Rubén Darío Estrada[1,2], Marcela Quintero[1], Alonso Moreno[3], Helle Munk Ravnborg[4]

[1] International Center for Tropical Agricultura (CIAT), [2]Consortium for the Sustainable Development of the Andean Ecoregion (CONDESAN), [3]GTZ and [4]Danish Institute for International Studies (DIIS)

for submission to the

CGIAR Challenge Program on WATER & FOOD

October, 2009

Acknowledgements

The authors of this manuscript acknowledge the following organizations that were important partners during the design and implementation of this project. Some of then were intended partners and users since the beginning of the project and other although unintended users and partners, their involvement during the project life time contributed to enrich its contents, approaches and to catalyze its impacts.

Program Preface:

The Challenge Program on Water and Food (CPWF) contributes to efforts of the international community to ensure global diversions of water to agriculture are maintained at the level of the year 2000. It is a multi-institutional research initiative that aims to increase the resilience of social and ecological systems through better water management for food production. Through its broad partnerships, it conducts research that leads to impact on the poor and to policy change.

The CPWF conducts action-oriented research in nine river basins in Africa, Asia and Latin America, focusing on crop water productivity, fisheries and aquatic ecosystems, community arrangements for sharing water, integrated river basin management, and institutions and policies for successful implementation of developments in the water-food-environment nexus.

Project Preface:

The project **"Payment for environmental services as a mechanism for promoting rural development in the upper watersheds of the tropics"** aimed to investigate and analyze the environmental externalities as a driver to promote social investment and a new dynamic and harmonic development in the rural sector. The environmental externalities were primarily water-related, which were quantified for selected Andean pilot watersheds. In these sites, the areas with higher potential to generate positive environmental externalities (environmental services) were prioritized. Moreover, in the prioritized areas the social and economic benefits (including multiplier effects by additional employments and income generated) derived from proposed land use changes to deliver environmental services were also assessed. Through the development of this project, the research team developed a methodological approach for quantifying and valuating the environmental services. Based on early results, the project through its development partners, make direct investments in the selected watersheds to test if financial or economic mechanisms (e.g. PES) were viable and feasible for providing environmental services under the existing socioeconomic context.

Between 2005 and 2008, the socioeconomic conditions changed drastically in the Andean region posing new challenges for the design and development of these financial mechanisms. This influenced the potential of environmental services as drivers of new rural. The project learned that private profitability of delivering these services is related to the type of watershed, and in general is low though can produce very high social benefits. When investment on infrastructure measures is proposed for improving a water-related environmental externality, this is rarely profitable at private prices. In most cases the investment is recouped by agricultural producers that not necessarily are the ones capturing the highest share of derived benefits and those sectors that do, do not contribute to pay back the investment cost neither compensate for the associated environmental benefit.

CPWF Project Report series:

Citation:

Estrada, R.D., M. Quintero, A. Moreno and H.M.Ranvborg. 2009. Payment for Environmental Services as a Mechanism for Promoting Rural Development in the Upper Watersheds of the Tropics. CPWF Project Report. 82 p.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

RESEARCH HIGHLIGHTS

This project was pioneer in Latin America by linking its purpose, methodological approach and analyses to direct interventions that aimed to tackle well-identified problems related to negative water-related environmental externalities. The project also has contributed to develop capacities in young professionals. The main research highlights are:

- A methodological approach to quantify and valuate water-related environmental services was developed including an approach to assess the potential of these services to positively impact socioeconomic conditions in watersheds.

- The magnitude of environmental services was determined for different watersheds. By prioritizing the sites where land users may deliver the highest amount of services, -based on hydrological modeling, an efficient and effective economic compensation per unit of service can be achieved. These sites corresponded to hydrological response units (HRUs) that constituted the level at which it was possible to study the trade off between increasing hydrological services vs. changes in socioeconomic benefits derived from different land use scenarios. This approach was proposed as a means to increase efficiency of investments in the watershed instead of promoting untargeted investments all over a watershed.

- The analysis of the isotopic signatures permitted to quantify the relationship between non-point sources of N and P and N and P concentrations in water bodies. This was specifically important for targeting areas that with a change on management practices may have a high contribution for reducing the pollution of water bodies.

- Poverty profiles were determined along with quality of life indicators and level of access to natural resources and this was related to eventual payments for environmental services in the studied watersheds

- The economic benefits associated with different land uses or management practices and desired environmental services were determined. Benefits include the marginal incomes for farmers and the social benefits derived from increasing the income and labor use with new proposed land uses (i.e. multiplier effects).

- A new methodological approach was developed to determine how changes in the provision of the environmental service may influence the competitiveness indexes of land use systems benefiting from that service. This is based on the cost of domestic resources and the social cost and benefit.

- Strategic alliances and financial schemes to improve the provision of environmental services were created based on results from the analyses conducted to quantify the service, to explore the willingness to cooperate, the investment cost of different land use scenarios and the socioeconomic impacts on farmers and society. As a result, different types of alliances and schemes were developed: alliances with the public (governments, environmental authorities and public water supply companies) and private (farmers associations, development agencies, etc) sectors; and different type of incentives, from direct payments and soft loans to technical assistance in agricultural technologies. The different incentives were selected according to the socioeconomic context of watershed farmers and water users.

- The ex-ante analysis was designed and conducted in a manner that provides the basis to compare with future ex-post analysis.

- To apply a hydrological model able to analyze the complex interactions between soil-land use-climate in a single watershed and determine those areas with important contributions to water and sediment yield, it was necessary to collect primary and secondary data related to soil characteristics, current land uses and covers, digital terrain models, climatic databases, etc. This information in the Andes is not easily available and accessible and as such the project contributed to create these basic databases needed for posterior analysis and ex-post assessments.

- The developed methodological approach has been applied in other watersheds different to those selected for the project, and thus has reached more beneficiaries than those originally intended, contributing to resolve social and environmental problems caused by water-related externalities in other sites.

- The design of PES-type schemes in selected watersheds revealed how difficult it is to use these mechanisms for increasing income of rural households as well as for conserving nature. The HRUs with the highest potential to deliver environmental services are not necessarily occupied by the poorest. Actually many poor people in Andean watersheds do not own lands, and as such, cannot capture the economic benefits derived from agricultural activities (e.g. producer's surpluses) and from compensation for environmental services. For them, land use changes promoted to provide environmental services in a watershed will only generate benefits by the multiplier effect resulting from eventual increments on labor use and associated income.

- The project enabled analysis of land use changes that may not require any compensation for environmental services to be implemented, as the opportunity cost is negative. In these cases, other types of incentives to stimulate the change are needed, such as soft loans that enable farmers to overcome up-front investment costs . One example was conservation agriculture in Colombia, a practice that impacts positively on soil characteristics that influence water flows and sediment retention while increasing farmer's income. Increasing small farmer access to cheaper loans is an effective mechanism to promote conservation practices with proven positive impacts on reducing sediment production and on increasing carbon sequestration. These practices however only favor the farmer by increasing the agricultural productivity and the net income, but reduce the economic benefits to others in terms of multiplier effects because labor use is reduced. This evidenced the difficulty to maximize private and social benefits by using environmental services as a new entry point of rural development strategies.

- Experimental economics methods were applied by using economic games to assess the willingness of different actors to cooperate for delivering better environmental services, whether by implementing land use changes or by making payments to environmental service providers. A lack of communication between actors in a watershed and the socioeconomic asymmetries between them impedes cooperation However, when communication is enhanced, cooperation notably increases. Since it was not possible to involve the wealthiest farmers in the games, the best alternative to promote their participation in schemes to promote land uses likely to provide environmental services could be through command-and-control measures.

EXECUTIVE SUMMARY

In 2004, the Water and Food Challenge Program of the CGIAR approved the proposal "Payment for Environmental Services (PES) as a mechanism for promoting rural development in the upper watersheds of the tropics" to be executed in five Andean watersheds. The selected watersheds were located in four different Andean countries (Colombia, Ecuador, Peru and Bolivia) and with contrasting biophysical and socioeconomic characteristics. The altitudinal range, rainfall amount and regime, agricultural production systems, poverty profiles, type of negative environmental externalities and actors were different across all these study sites. These watersheds contrasted with the other watersheds of the CPWF selected in other parts of the world in terms of size being the Andean ones much smaller. However these watersheds were representative of the type of those found in the Andes: small watersheds with strong slopes, important climatic variations along their altitudinal range (precipitation and temperature), short-term stream response, great altitudinal variations in relative short distances (from 1000 to 4000 m altitude), heterogeneous soil types and different levels of agricultural productivity. Specifically the studied watersheds were: the Fuquene Lake watershed (Colombia); the Ambato River watershed (Ecuador); the Jequetepeque River watershed (Peru); the Altomayo watershed (Peru) and the Tunari mountains micro-watersheds (Bolivia).

In the Andean watersheds, most of the farmers located in the steeper lands are poor. Thus, they seek new sources of income including compensation for environmental services would help to increase their incomes. In this document the potential that the provision of water-related environmental services may have as a new income source is discussed based on project outputs and experiences.

Between 2005 and 2008, the period over which the project was executed, the Andean region countries suffered strong changes in their macroeconomic conditions. In 2003 and 2004 when the idea to compensate for environmental services started to be proposed by project team members, the challenge was to seek for new income sources for Andean farmers under a panorama of continued reduction of agricultural products prices. In 2007, however, the compensations for environmental services seemed to be insufficient to counteract the unexpected increment in food prices. In 2008, when the project ended, the increase in agricultural input prices and the decline in agricultural products prices made PES a scheme viable under two possible situations:) For farmers which production systems loss their competitiveness and then were needing of alternatives (e.g. receive awards for implementing new land uses that deliver ES and are not high-input demanding) or providing ES payments for current land uses that with changes on management practices can be beneficial for the environment while improving its competitiveness (e.g. by increasing the use of local labor). During the initial years of the project, the methodological approach focused on a) Determining the magnitude of the hydrological externalities, b) Prioritizing the hydrological response units (HRUs) in a watershed where farmers have the highest potential to make land use or management changes to increase environmental services and be compensated; c) Determining the poverty profiles of these farmers and their level of access to natural resources and environmental services payments; and d) the quantifying of the socioeconomic benefits derived from the land use changes and their distribution (e.g. farmers, society, etc). Under the abovementioned changes, the project team incorporated analysis of how changes in the provision of a water-related environmental service (e.g. increase in stream flows during dry season, reduction in sediment yield, increment in water yields, etc) may result in changes in the competitiveness of farming systems by using the competitiveness index as indicator (based on the cost of domestic resources and the social benefits and costs).

In terms of direct interventions in the watersheds, strategic alliances were created to collect funds for providing incentives to farmers willing to implement land use changes that were likely to impact a given environmental service. The strategic alliances were made with public and private actors, from environmental authorities and local governments to water users and international organizations. The compensations went beyond direct payments, including technical support assistance, facilitation of agricultural inputs, soft loans, etc.

To generate the analytical outputs a series of activities were conducted. One, hydrological models (i.e. SWAT – Soil and Water Assessment Tool) were applied refining its parameters for the Andes throughout the project execution. Two, a model to evaluate different land use scenarios from a socioeconomic and environmental perspective and to determine the shadow price of non-market goods and services was developed (i.e. ECOSAUT – A model for social, economic and environmental evaluation of land uses). Three, basic biophysical data to quantify hydrological externalities was collected for the study sites and improved when necessary with primary data (soil type units, digital elevation models, land use maps, climatic stations and water flow gauges data. Four, surveys for poverty profiles were developed and economic data of current farming systems collected. Five, with the information gathered and generated, HRUs for all studied watersheds were determined along with their corresponding water balances in order to prioritize those with high impact on hydrological externalities. Six, land use scenarios were evaluated to understand opportunity costs. Seven, poverty profiles were defined and economic games applied to explore willingness of actors to cooperate towards the positive modification of environmental externalities.

In summary the main project lessons learned are:

- An understanding of the spatial distribution and temporal hydrological behavior of the identified HRUs is essential to achieve a high efficiency in the use of financial resources to compensate for environmental services
- There is a great difference in using schemes of payments for environmental services as a mechanism for enabling the conservation of natural ecosystems vs. for increasing income and improving rural population wellbeing. The latter objective requires broader analysis to understand all the derived socioeconomic benefits of land use/management changes at different scales: farm, sub-watershed; watershed and the society in general. In addition, the HRUs with the highest potential to deliver environmental services are not necessarily

occupied by the poorest. Many poor people in Andean watersheds do not own lands and as such, and therefore cannot capture the economic benefits derived from agricultural activities (e.g. producer’s surpluses) and from compensations for environmental services. For them, land use changes promoted to provide environmental services in a watershed will only generate benefits by the multiplier effect resulting from eventual increments in labor use and income.

- When a land use is identified as being appropriate to improve the provision of environmental services and has a negative opportunity cost, other types of incentives to stimulate the change are needed, such as soft loans. One example was conservation agriculture in Colombia, a practice that positively impacts soil characteristics by improving stream flows regulation and reducing sediment production while increasing farmer income. Increased accessibility to cheaper loans by small farmers showed to be an effective mechanism to promote a practice with proven positive impacts on reducing sediment yields as well as on increasing carbon sequestration (Quintero, 2009). However, these practices only favor the farmer by increasing the agricultural productivity and the net income, but since labor use is reduced the economic benefits to others may not exist. This poses a major obstacle in attempting to maximize private and social benefits by using environmental services as an entry point in new rural development strategies.
- The lack of communication between actors in a watershed and the socioeconomic asymmetries (i.e. smallholders dedicated to agriculture vs. large dairy cattle ranchers) between them impede cooperation that can help improve the provision of environmental services. However when communication is enhanced the cooperation is increased notably. Also, involving the wealthiest farmers in the economic games was difficult. This may indicate that the best alternative to promote their participation in providing environmental services compensations is through command-and-control mechanisms (e.g. laws and regulations, not prices).
- Many poor people in Andean watersheds do not own lands. Thus, they cannot capture some of economic benefits derived from agricultural activities (e.g. producer’s surpluses) and from compensations for environmental services. For the landless, land use changes promoted to provide environmental services in a watershed will only generate benefits via a multiplier effect resulting from increases of labor use and income.
- The investment on perpetual PES schemes likely to deliver and maintain the desired flow of environmental services is a long-term investment, and as such, are affected when unfavorable macroeconomic changes occur in the countries. Thus public investment is deviated to other immediate priorities and private actors are only willing to invest in schemes to provide environmental services if they can have an important share of the derived economic benefits.

INTRODUCTION

In 2004, the CGIAR Challenge Program on Water and Food (CPWF) approved the proposal "Payment for Environmental Services (PES) as a mechanism for promoting rural development in the upper watersheds of the tropics" to be executed in five Andean watersheds. The selected watersheds were located in four different Andean countries (Colombia, Ecuador, Peru and Bolivia) (figure 1) and with contrasting biophysical and socioeconomic characteristics. The altitudinal range, rainfall amount and regime, agricultural production systems, poverty profiles, type of negative environmental externalities and actors were different across all these study sites. These watersheds contrasted with the other watersheds of the CPWF selected in other parts of the world in terms of its size being the Andean ones much smaller. However the selected sites represented the typical Andean watersheds: small watersheds with severe slopes, important climatic variations along their altitudinal range (precipitation and temperature), short-term stream response, substantial elevation variations in relative short distances (from 1000 to 4000 m altitude), heterogeneous soil types and different levels of agricultural productivity. Specifically, the studied watersheds were: the Fuquene Lake watershed (Colombia); the Ambato River watershed (Ecuador); the Jequetepeque River watershed (Peru); the Altomayo watershed (Peru) and the Tunari mountains micro-watersheds (Bolivia).

Figure 1. Location of selected watersheds.

In the Andean watersheds, most farmers located in the steeper lands are poor. New sources of income such as compensation for environmental services would help to increase the incomes of these farmers and thus will contribute to the overall goal of the project that was to stimulate the economic recognition of water-related environmental externalities in order to promote PES schemes that can improve ES delivery along improvements in rural income. In this document the potential of the provision of water-related environmental services to accomplish this goal is discussed based on the basis of project outputs and experiences.

Between 2005 and 2008, the period over which the project was conducted, the Andean region countries suffered strong changes in their macroeconomic conditions. In 2003 and 2004 when the idea to compensate for environmental services started to be proposed by project team members, the challenge was to seek for new income sources for Andean farmers under a panorama of continued reduction in agricultural products prices. In 2007, the compensations for environmental services seemed to be insufficient to counteract an unexpected increase in food prices. In 2008, when the project ended, the increase in agricultural input prices and the decrease in agricultural products prices made a PES scheme viable under two possible situations:) For farmers which production systems loss their competitiveness and then were needing of alternatives (e.g. receive awards for implementing new land uses that deliver ES and are not high-input demanding) or providing ES payments for current land uses that with changes on management practices can be beneficial for the environment while improving its competitiveness (e.g. by increasing the use of local labor).

During the initial years of the project, the methodological approach was focused on a) Determining the magnitude of the hydrological externalities, b) Prioritizing the hydrological response units (HRUs) in a watershed where farmers have the highest potential to make land use or management changes to increase environmental services and be compensated ; c) Determining the poverty profiles of these farmers and their level of access to natural resources and eventual environmental services payments; and d) the quantifying of the socioeconomic benefits derived from the land use changes that can be captured by farmers and society. Under the abovementioned changes, the project team analyzed how changes in the provision of a water-related environmental service (e.g. increase in water flows during dry season, reduction in sediment yield, increment in water yields, etc) may result in changes in the competitiveness of farming systems. (A competitiveness index was used as indicator based on the cost of domestic resources and the social benefits and costs.)

In terms of direct interventions in the watersheds, strategic alliances were created to collect funds for providing incentives to farmers willing to implement land use changes likely to impact a given environmental service. The strategic alliances were made with public and private actors, from environmental authorities and local governments to water users and international organizations. The compensations went beyond direct payments, and were turned into technical support assistance, facilitation of agricultural inputs, soft loans, etc.

This manuscript summarizes the research activities and outputs achieved in the selected watersheds; the evolution of the created strategic alliances; the impacts attributable to the project; the lessons learned and new research issues that need to be addressed by future research projects and that have resulted from the last macroeconomic changes in the Andean countries.

Specific information about the different research activities, its methods and results are found in the references cited in this document and freely available. This manuscript is the first effort to integrate the different methods and perspectives adopted by this project to understand the potential of PES schemes to conserve environmental services and generate rural development in the Andes.

Brief description of study sites

<u>Fuquene watershed (Colombia)</u>

The Lake Fuquene watershed is located in the valleys of Ubaté and Chiquinquirá, north of Bogotá, the capital of Colombia (South America) (N 05 20’ W 73 51’). The soils of this location are

Andisols, Inceptisols and Histosols (IGAC 2000). The mean monthly humidity varies between 70 and 80%. The annual mean precipitation is 610 mm (JICA 2000).

Concern for the lake's conservation began in the latter part of the twentieth century due to the advanced and accelerated process of deterioration from excessively high levels of phosphates and nitrates and the proliferation of aquatic plants, which have accelerated eutrophication. The surface covered by water has been reduced considerably, making navigation impossible. The downstream municipalities, whose aqueducts depend partially or totally on waters from the Suarez River, which begins at the outlet of the lake, are concerned about the future of their water-supply systems.

A systematic study using secondary data was contracted by the regional environmental authority CAR (Autonomous Regional Corporation for Cundinamarca Province). Results suggested that cattle producers are responsible for 80% of the pollutants that flow into the lake. Fertilizers from the pastures, animal manure and urine wastes infiltrate the waters permanently (CTI et al. 2000). However, the producers do not invest in any action or resource to revert or minimize the impact. Additionally, the industry and population around the lake lack appropriate treatment systems for residual waters, dumping wastes directly into superficial waters. According to this study, the annual contribution of total loads including point and non-point sources was estimated at 48,123 kg/day of total N and 6,156 kg/day of total P (CTI et al. 2000).

The area lacks sound environmental management, both in the upper parts of the catchment where paramo ecosystems (a type of high alpine grasslands) are replaced by potato crops and in the valley bottom where cattle ranchers overexploit land and destroy the wetlands. From a socioeconomic standpoint, inequity is characteristic, with the most productive areas in hands of large landholders, while the hillsides are for smallholders. In summary, the accumulated effect of individual actions at plot scale are having a regional impact on the quality of water resources. Decisions taken at the plot level are determining a water-quality problem of regional characteristics.

The main local partners of the project were CAR (Corporación Autonoma Regional), the Environmental Program of GTZ in Colombia and FUNDESOT (Fundacion para el Desarrollo Sostenible Territorial).

<u>Altomayo watershed (Peru) (Rumiyacu and Mishquiyacu microwatersheds)</u>

The Rumiyacu and Mishquiyacu micro-watersheds, located in the Altomayo transitional zone between the Peruvian Andes and the Amazon (1022-1539 m.a.s.l), encompass 7.3 km2, and have an average annual precipitation of 1408 mm. They supply drinking water to the town of Moyobamba, benefiting about 40,000 inhabitants. The Mishquiyacu River is the regular source of water supply, while during shortages water is also taken from the Rumiyacu.

The two micro-watersheds are mostly covered by natural forest (61%); the remainder is under a mosaic of slash-and-burn systems, coffee, and permanent pastures. However, deforestation in the

Altomayo region is at a staggering 4.2% annual rate (PEAM 2004), due to farm establishment by immigrants who make up more than half of Moyobamba Province's population (PEAM 2004). Their land is untitled; most migrants have taken possession through deforestation. Slash-and-burn systems include subsistence crops (mainly maize), which are succeeded by pastures when soil productivity decreases. 42% of farmers cultivate coffee, but under currently low productivity.

The replacement of native vegetation by other land uses has caused high sediment loads, thus from 2003 increasing the drinking-water treatment costs of Moyobamba's water and sanitation company (EPS -- a public entity but operating under private law) by about 20%, (Quintero et al. 2005, F. Aspajo, pers.comm. 2005). Hence, the Municipality of Moyobamba declared the watersheds as Municipal Conservation Area, with the purpose of conserving remaining forests and to promote sustainable land uses in already disturbed areas. EPS also explored options to reduce upstream sediments and simultaneously improve livelihoods.

The main local partners of the projects were: The water supply and sanitation company (EPS-Entidad Prestadora de Servicios de Saneamiento Moyabamba), The Altomayo Especial Program (PEAM), the PDRS-GTZ project (Rural Development Program of the GTZ), InWEnt, Deutscher Entwicklungsdienst (DED)- Social and Technical Cooperation and the municipalities of Moyobamba and Nueva Cajamarca.

Jequetepeque watershed (Peru)

The Jequetepeque River watershed is located in the Peruvian Northern Andes, stretching from the Peruvian coast to the high Andes (4188 m altitude) and covering an area of 4,372.50 km^2. The annual precipitation ranges between 500-1000 mm. The rainfall is highly variable and during extreme drought periods can be as low as 200 mm in the lower lands or can cause catastrophic flooding events during El Nino phenomenon. In the upper parts, there is rainfall during all months; the January-May period is the wettest one. In the lower part, the precipitation is concentrated in only few months.

The watershed comprises six provinces and 30 districts belonging to two departments: La Libertad and Cajamarca. The population in the watershed is about 350,000 inhabitants. 80% of the poor households are located in the upper parts of the watershed and the per capita income is on average US$750 yr^{-1}, 25% below the poverty line. Subsistence and rainfed agriculture are the main economic activities of the communities located in the middle and upper parts, while in the lower parts the intensive and irrigated agriculture is predominant. The main environmental externalities are related with the high production of sediments and the water pollution caused by deforestation, unsustainable agricultural systems, and mining. The main local partners of the project were CEDEPAS, ASPADERUC, CESAH Project (WWF-IIED), and some municipalities (Moreno & Renner, 2007)

Ambato watershed (Ecuador)

The Ambato River watershed covers 60% of the Tungurahua province territory located in the central part of Ecuador. Its surface area is approximately of 1300 Km^2 with about 310.000 inhabitants. Due to its strategic location in the country, this watershed produces a wide variety of products that are commercialized in the Ecuadorian coast, the Andean region and the eastern part of the country. The highest part of the watershed at 6310 m altitude corresponds to the Chimborazo volcano. This volcano and the Carihuairazo supplies water to the province. 40% of the watershed is located above the 3500 m altitude where only 5% of its total population is located. In the upper parts the natural ecosystem is páramo (high alpine grasslands) and the main economic activity is the extensive livestock. The average net income per person is US$1,000 yr^{-1} and the average farm area is 1 hectare. The lower part of the watershed, located between 2200 and 2800 m altitude, hosts 70% of the total population. The main economic activities are floriculture, small animals rising, handicrafts and industry (Moreno and Renner, 2007)

The main environmental issues are related to the overexploitation of the páramo ecosystem (that covers about 55,000 ha), intensive and unsustainable agriculture, water pollution, inefficient water use and unequal water distribution. All these factors contribute to frequent social conflicts. Water demand exceeds the water availability by 40%, creating a water deficit of 903 millions m^3 of water every year. This poses a constant pressure on natural areas that are important for water supply.

The local partners of the projects were: GESOREN program of the GTZ (Gestion Sostenible de los Recursos Naturales), PROMACH (Proyecto de Manejo de Cuencas Hidrograficas) –a project of the Tungurahua Provincial Government, and Randi-Randi Corporation (NGO).

<u>Microwatershed of the Tunari Mountains (Bolivia)</u>

The Tunari Mountains are located in the Cochabamba department of Bolivia. This area was selected because of its context, enabling the study of relationships between poverty and potential schemes of payment for environmental services. The mountain range is home to 39 microwatersheds and about 45 communities living in the upper parts, practicing agriculture as their main economic activity. In the lower areas, Community-based Territorial Organizations (Organizaciones Territoriales de Base – OTB’s) are common, located in the transitional zone between the rural and urban sector. In these watersheds, diverse interventions for improving natural resources management have been conducted through PROMIC (Programa de Manejo Integral de Cuencas). These interventions have been carried out in the Taquiña, Pajcha, Pintu Mayu, La Llave, Huallaquea, Khora Tiquipaya and Chozaya micro-watersheds. The water that drains from the Tunari watersheds enters the Cochabamba valley that has a population of about 700,000 inhabitants and 450 Km^2. The water resources coming from these mountains are important for the provision of potable and irrigation water in the lower areas, and at the same time are crucial for the subsistence agriculture in the upper areas. The appropriate land use of the upper areas is essential for controlling and mitigating the high flooding risk of the Cochabamba valley. The project focused its activities on the Taquiña, Pajcha, Pintu Mayu, and Khora Tiquipaya watersheds. The main local partner was PROMIC.

PROJECT OBJECTIVES

The overall goal of the project was to alleviate poverty and enhance sustainability in upper catchments by increasing the flow of resources from governments and civil society to poor rural producers that impact positively on water-related environmental externalities while strengthening the competitive capacity of the poor through greater food security, higher incomes, and better administrative and organizational skills.

The results of the project can be grouped according to two main objectives: 1) To demonstrate the potential and feasibility of schemes of payments for environmental services to reduce poverty in the selected watersheds; 2) Generate appropriate information and institutional platforms to create strategic alliances needed to implement PES pilot schemes and new land uses or management practices likely to deliver beneficial watershed services.

1 Objective 1: To demonstrate the potential and feasibility of schemes of payments for environmental services to reduce poverty

To accomplish this objective, different methods were implemented in order to achieve the following outputs: 1) the main water-related environmental externality was quantified in each selected watershed by means of hydrological modeling. The externalities were mainly related to the production of sediments that affect water quality and the seasonal water yields (peak flows and base flows during dry season); 2) Poverty profiles were determined in the watersheds and also an assessment of the state of access to natural resources (land and water) was conducted; 3) The opportunity costs and profitability of different land use scenarios likely to result in positive effects on water-related environmental services were determined.

Methods

Quantification of water-related environmental externalities through hydrological modeling

The SWAT model (version 99.1) was used in all case studies. Through the ArcView-SWAT interface, information about topography (digital elevation model), soils (soil map and survey), weather (climatic stations and its coordinates) and land use (most recent land-use map) were combined for simulation. Values of soil characteristics per soil map units were incorporated in the model such us soil depth, bulk density, available water capacity, saturated hydraulic conductivity, clay, sand, silt and organic matter content. The climatic information for simulating the water balance consisted of daily rainfall, maximum and minimum temperatures, and monthly radiation. Climatic datasets were entered into the model for the longest available time periods. In most cases they were available for the last 10 to 20 years.

For the simulation, the watersheds were delineated using a digital elevation model. Sub-watersheds and Hydrological Response Units (HRUs) were defined. HRUs are spatial units with unique soil and land use characteristics. For each HRU, SWAT estimated the soil loss through water erosion and the water yield, thus featuring the two main hydrological services (environmental externalities) of interest. For this, the water balance per HRU was calculated taking into account three storage volumes: soil profile, shallow and deep aquifer. The soil profile was subdivided into multiple layers, according to the number of horizons identified in soil-profile descriptions. The soil-water processes modeled with SWAT included infiltration, evaporation, plant uptake, lateral flow and percolation to lower layers. Thus, we calculated water yields (total amount of water leaving the HRU and entering the main channel) and sediment yields (amount of sediment contributed by the HRU to the stream) (Neitsch et al. 1999), and routed them through drainage to the watershed outlet.

The model was calibrated to reduce parameter uncertainty and increase robustness of the results, i.e. some parameters were marginally adjusted until the best possible correspondence between observed and simulated stream flow at the basin outlet was obtained. During calibration, the runoff curve number, the saturated hydraulic conductivity, and the USLE (Universal Soil Loss Equation) C and P factors were varied. Runoff parameters, water-holding capacity and saturated hydraulic conductivity have shown high sensitivity in other studies (i.e. Lenhart et al. 2005; Jakajrisnhan et al. 2005; Govender and Everson 2005; Heuvelmans et al. 2005). Once calibrated, different land-use scenarios were model-evaluated for their effects on water and sediment yields (Jakajrisnhan et al. 2005).

In addition, in one of the cases (i.e. Tunari, Boliva), other models such as LISEM, Muskingun-Cunge and Flo2d were used to determine the effect of soil conservation practices on the reduction of flooding risk.

Poverty profiles and state of access and management to and of water resources

The determination of poverty profiles was based on local perceptions about the quality of life. These perceptions were obtained through the well-being classification made for representative communities of the watersheds. These communities were selected according to the diverse environmental, social and cultural characteristics found in the watersheds such as different altitudinal ranges, ethnic groups, land distribution and accessibility, among others as recommended by the poverty profiles methodology by Ravnborg et al. (1999). For each identified community, the well-being classification in three levels was made by key informants and described in local terms. Based on these descriptions, well-being indicators were identified and used for a survey design which was applied in the communities to obtain information about the well-being status. The surveys were applied for a representative households sample in each watershed. To select the households, the number of communities was determined initially and later, the size of the sample was estimated and the households were selected randomly.

The application of the survey permitted to evaluate the households for the identified well-being indicators, and therefore to define their corresponding poverty level. Each family was scored for each indicator according to three possible scores: 33, 67 or 100. The final poverty qualification was calculated as the averaged score obtained per each family after evaluating all indicators. With this information, histograms were built showing the poverty index frequency and the households were classified into three categories: not poor, less poor and poorer.

The variables that were mostly used to classify the households into different poverty classes were related to income sources (land tenure, animals tenure, agricultural products commercialization, non-agricultural income, etc); basic needs fulfillment (food security, house tenure, health services) and family characteristics (leadership in the family, capacity to ensure child education, capacity to contract labor for agricultural activities, etc).

With respect to access to and management of water, the access to irrigation and the parcel location in the irrigation systems (if existing) with respect to main and secondary channels were analyzed , as well as the availability to water throughout the year.

Economic analysis of opportunity costs for different land use alternatives

Three different approaches were used to assess the opportunity cost of land use alternatives for HRUs (defined initially through hydrological modeling). The selected land use alternatives were those likely to have a positive impact on the hydrological service (environmental service) and that at the same time were interesting for local farmers. The different approaches contrast the proposed land use change and the "business-as-usual" land use (or the baseline). When the environmental service has potential to be generated in areas under land uses with low levels of labor use, the opportunity cost was determined based on the direct benefits and costs for the farmer. However, when land use changes were proposed for areas with more intensive agricultural uses where the consequence of implementing the proposed land use change may imply a reduction on labor use or income, the impact on social benefits by the multiplier effect of impacting the levels of labor and income was assessed through a value chain analysis (De Janvry and Gilkman 1991) in addition to the calculation of the opportunity cost for the farmer.

For these two cases, the ECOSAUT model –developed by this project (Quintero et al. 2006) was used which by means of linear programming maximizes farmer's net income under imposed social, economical and environmental constraints. The model considers multiple land use systems and therefore, allows to quantify the marginal benefits between the baseline land use system and the alternatives. In addition, for the optimal solution, the shadow price for the most restrictive variable was determined. When this variable corresponded to a non-market good or service (e.g. an environmental service such us water and sediment yields), the shadow price corresponded to its price. This shadow price is equivalent to the opportunity cost of that resource or service (restrictive variable in the model) for the farmer. Thus, this price is indicative of the amount that may be negotiated in an eventual PES scheme design.

The model is multi-period as it simulates the behavior of the variables throughout the time (up to 10 years) such us variations on sediment and water yield, agricultural productivity, labor use, cash flows, etc. The model is suitable to simulate mixed production systems such as those that commit land for both crop and livestock production. It also permits modeling of the interdependency between the production of crop residues and their use for cattle raising, generating a nutritional balance according to the nutritional requirements of the animals and therefore, determining the carrying capacity.

A third approach was adopted when the improvement of a water-related environmental service had implications for the competitiveness of agricultural systems and as such for its sustainability in the middle and long term. In the same way, improvements in the agricultural production can have impacts on the economic benefits (i.e. surpluses) realized by producers and consumers. This approach was applied for the Ambato watershed, where the operation of a reservoir prompted to initiate operation will have impacts on these aspects.

From the methodological standpoint, an analysis to determine changes in the competitiveness was conducted by estimating indicators of competitiveness. The most appropriate method is through a general equilibrium model of the entire economy. However, that was not possible in this case due to time and resource constraints, so an alternative approach based on the Policy Analysis Matrix (PAM; Monke and Pearson 1989) was adopted. This approach allows the use of secondary data and requires the calculation of social values (shadow prices) for inputs and outputs. To determine the shadow price of the land and labor under different technological alternatives, an optimization model (i.e. ECOSAUT) can be used. It is also appropriate to quantify the environmental and social externalities generated by the system and examine growth linkages (employment and revenues) with other sectors of the economy.

The PAM framework allows direct estimation of competitiveness, which is related to the social profitability of an activity under consideration. More specifically, the elements of the PAM include both social and private costs, benefits and profitability and these can be used to estimate two indicators of competitiveness, the Domestic Resource Cost or the Social Cost Benefit indexes (Kydd et al. 1997, Monke and Pearson 1989). The SCB is considered the better indicator when an important part of the costs is represented by non-tradable goods. The DRC and SCB measure the efficiency of using domestic resources instead of importing the products. The PAM provides information about profitability based on both private (actual) prices and social values, where the latter are those prices that would exist in the absence of various types of distortions (often due to policy or market failures). In this study the analyses compared the opportunity costs of production with the social benefits that this generates, eliminating all quantifiable market distortions. Likewise, it estimates the opportunity cost of saving one unit of foreign exchange through the domestic production (CIAT 1993, Masters and Winter-Nelson 1995).

The PAM is constructed taking into account the revenues, costs and benefits at both private and social prices. Private prices refer to the market prices while social prices are the opportunity cost of the domestic resources. The later includes the cost of local resources that cannot be trade internationally (e.g. water, labor, local capital, etc.) but are essential for producing tradable goods. The costs are divided into tradable and non-tradable resources. The DRC is given by the following:

DRC= NTC*/(P*-TC*)

Where NTC* is the unit social value of non-tradable inputs used in production, P* is the social price and TC* is the unit social value of tradable inputs used in milk production. A value of the DRC less than 1.0 indicates that the social value of domestic resources is less than the social value of the output less tradable costs, indicating that the country has a comparative advantage. If the DRC is equal to 1.0, the country could either import or produce domestically. If the value is greater than 1.0 or less than 0.0, there are clear competitive disadvantages. In the former case the DRC is greater than the value of the foreign exchange used in their importation. In the latter case more foreign exchange is used than the true value of the goods for the country based on the international market.

The social values of input prices reflect the shadow prices of the goods used in the production at the farm level. By design, social prices do not take into account the taxes, subsidies, import tariffs, quotas and other governmental controls that affect the market price. The tradable goods category includes inputs such as fertilizers, fuel, machinery, etc. which can be imported or exported, whereas the non-tradable goods are assumed only to be available at the specific country level (e.g., water, land and labor).

One of the challenges of calculating a DRC is allocation of input costs to tradable and non-tradable factors. The two types of goods usually are integrated in a given input cost. For example; in the preparation of the land for planting pastures, an important component is the depreciation of the tractor, which is a tradable good, while the cost of the operator is a non-tradable input. In this analysis the budget line items of the production costs should be detailed and in each one of them the values of the tradable and non-tradable goods (labor and capital) are estimated. The challenge of input classification into tradable and nontradable goods implies that the SCB may be preferred in many situations (Masters and Winter-Nelson 1995)

The SCB is given by the following:

SCB= (NTC+TC) /P

where the elements are as defined for the DRC calculation. Note that the SCB is essentially a different arrangement of the information used to calculate the DRC. The system is competitive if this value is greater than 0.0 and less than 1.0; this indicates the total social costs are less than the social benefits (alternatively, this means that the activity is socially profitable). The advantage

of this indicator is that, unlike the DRC, it is not necessary to separate the tradable and non-tradable components of several production costs when these components are integrated. In fact, Monke and Pearson (1989) do not recommend disaggregating these costs because it is a formidable challenge to assign the proportion of tradable and non-tradable goods
Generally when the analyses are done at the farm level, the investments in infrastructure and equipment are considered capital assets, whose yearly cost is the value of the depreciation plus the value of the capital involved in the process. Given the high social interest rates (7-10% annually), this is a high cost for the whole system and does not reflect the great versatility of production systems that are using a high proportion of labor. Such systems are more competitive when the shadow price of the daily wage is low.

Results

Hydrological modeling and economic analysis to quantify water-related environmental services

Fuquene watershed

The hydrological analysis conducted in this watershed was useful to the relationships between land uses and water quantity, quality and sedimentation, using the Soil and Water Assessment Tool (SWAT)for a 10 years simulation periodIn the context of the biophysical and socioeconomic heterogeneity of this Andean watershed, the spatial information helped identify the HRUs and prioritize them according to their environmental benefit (i.e. reduction of sediments). Not all HRUs had the same importance at the moment of valuing their role in providing this environmental service. In this watershed, the role in the production of sediments to the lake was a priority given the movement of phosphates and nitrates towards the lake within the sediments (Rubiano et al. 2005). Criteria for selecting the relevant HRUs were also dependent on the scale of the externalities to be assessed. At this point, international water-quality standards were an alternative source of information since local limits are not clearly defined. Figure 2 shows the HRUs contributing the most to leached nitrates in Fúquene Lake.

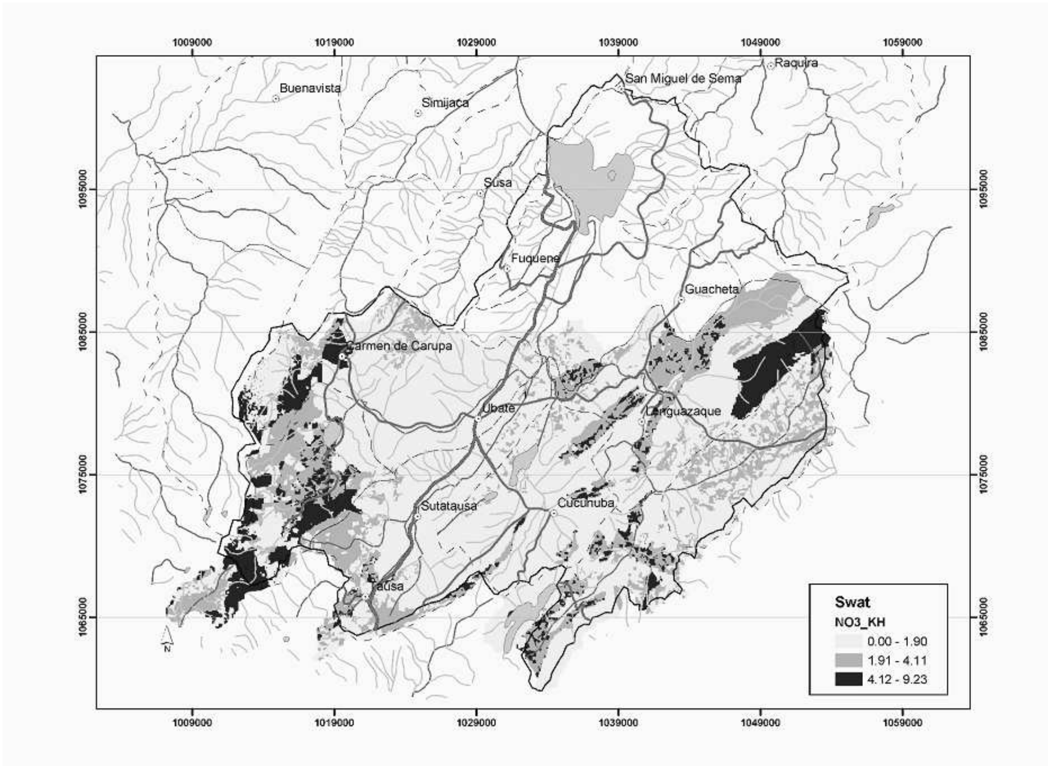

Figure 2. Soil and Water Assessment Tool simulation of concentration of nitrates in the area of Fúquene.

The SWAT model simulated amounts of NO3-N contained in runoff, lateral flow and percolation as products of the volume of water and the average concentration of nitrates in soil layers (McElroy et al. 1976). A loading function was used to calculate the transport of organic N (Williams and Hann 1978) and modified for applying to individual runoff events. The loading function estimates the daily organic N runoff loss based on the concentration of organic N in the topsoil layer, sediment yield and the enrichment ratio (the concentration of organic N in the sediment divided by that in the soil) (Rubiano et al. 2006).

Data on water quality, fertilizer use and quantity for each cropping system were included in the simulation. Tracing the contribution of N and P made by each cropping system to the water system was done using dN15 and dO18 isotopes. Stable isotopes could determine the contribution of old and new water to a stream and to other components of the catchment during periods of variable runoff, integrating temporal and spatial variability (Kendall and Caldwell 1998). The analysis of the isotopic signatures permitted to assign to the sediments the higher contribution source of nitrates with a figure of 43.6% followed by fertilizers with 38.3% and organic wastes with 18.1%. Summing up the three sources, areas in pasture were contributing with 17.4 while cropland were accounting for the 43%. Nitrates attached to sediments are accounting for more than a half of cropland contribution (Rubiano 2005).

Based on these results, the SWAT analysis permitted to prioritize the cropland areas with the highest sediment contribution to the main channels. 329 ha for their impact on the sediment yield levels were prioritized, in which N and P move until reaching the water courses. Some of these HRUs were located in the upper watershed; others in the intermediate part of it. This altitudinal gradient implies differences in the production systems and climatic characteristics and, therefore, a variation in the value of the environmental service and in the opportunity costs of changing the land use. Main results are summarized below and are detailed in Rubiano et al. (2006).

The ex-ante economic analysis considered two main scenarios: production systems with conventional tillage (CT) (current scenario) and production systems implemented with conservation tillage (or reduced tillage –RT) (minimum tillage, direct drilling, and green manures). The CT rotation is traditional potatoes rotated every 2 years with other 2-years of pasture (ryegrass). The RT rotation is potatoes with an oat cover crop previous to potato sowing. In these parcels, oat and potatoes are also rotated with pastures as in CT. RT is distinguished from CT because oat cover crops are included in the rotation along with reduced tillage. The CT systems instead use intensively rotary tillers. Tables 1 and 2 show that net incomes of upper and middle catchment farmers implementing conservation farming schemes are increased while the negative externality is reduced (a reduction of sediment yield by about 50%). The environmental impact was assessed using results from simulations with SWAT. From the standpoint of generating jobs, changes in the management practices in the upper catchment produce a reduction in the contracted labor; however this is compensated with an increase in the levels of employment obtained with the technological change in the middle catchment.

Shadow prices were calculated for the HRUs selected in Fúquene by running a sensitivity analysis in the linear programming model (i.e. ECOSAUT). Since the model was fed with actual costs and benefits of the evaluated land use alternatives, the sensitivity of the state variables (including sediment production) were indicated also in monetary terms. These prices were obtained regarding production systems with CT but imposing a limit to the production of sediments. Under these conditions the shadow price for reducing one ton of sediments was US$85 and US$24, respectively, for farmers located in the upper and middle catchments. This price corresponds to the cost of reducing one ton of sediments in the first semester of ten consecutives semesters evaluated (the ex-ante analysis was conducted for 10 semesters). It means that the modification of the negative externality (sediments) is more important in that semester due to temporal variations related to crops rotation and climatic conditions.

From a practical perspective, it is not effective to transfer this value just in one semester. For this reason and using the marginal changes in net incomes and sediments yields, the reduction of one ton of sediments costs US$ 18 and US$11, respectively, for the upper and middle catchment farmer. Regarding the obvious difficulties of monitoring actual annual changes in sediment yields caused by the farmers' production systems, it could be more efficient to calculate the opportunity cost of one hectare if taken out of the current production systems in order to accomplish erosion limits. The opportunity cost per hectare is US$1578 for farmers located in the upper catchment vs. US$1255 for middle-catchment farmers. In relative terms, the difference between opportunity cost (per ha) of upper lands vs. middle catchment lands is smaller than the difference between the shadow price of a ton of sediments reduced in the upper catchment vs. in middle catchment. This is explained by the fact that the estimation of land opportunity costs only reflects the differences on profitability among the production systems –or rotations; while the shadow price captures the differences in sediments yield as well as of profitability of the system. Although the shadow price seems to be a more precise method for approaching the real price of the externality (sediment production), in pragmatic terms could be better to use the opportunity costs of land as an element for negotiation and designing PES schemes. However, as more sophisticated a PES scheme is desired to be, as better will be to use shadow prices as it gives the price of the externality (and the service) and its importance in monetary terms for different areas in the watershed.

As shown previously (Tables 1 and 2), however, this cost can be avoided if conservation farming practices are offered and adopted by Fúquene farmers because net income is improved and negative externalities (sediment yield and) are reduced.

Table 1. Changes in net incomes and externalities with two different alternatives for managing soils and crops in upper catchment farms; Fúquene case study (Source: Rubiano et al. 2006)

	Scenario 1 **Production systems with traditional tillage**	**Scenario 2** **Production systems with conservation farming practices**
Net income (US$)	1,662,223	1,975,922
Sediment (t)	72,422	43,761
Employment (no. workdays)	79,067	67,753

Table 2. Changes in net incomes and externalities with two different alternatives for managing soils and crops in middle catchment farms; Fúquene case study (Source; Rubiano et al. 2006).

	Scenario 1 **Production systems with traditional tillage**	**Scenario 2** **Production systems with conservation farming practices**
Net income (US$)	1,223,820	1,235,716
Sediments (t)	95,414	48,730
Employment (no. workdays)	43,576	70,714

After ex-ante analysis, the project conducted an ex-post analysis using ECOSAUT for economic analysis and soil local measurements to determine to what extend conservation tillage effects were consistent with those assessed during the ex-ante analysis. For this purpose, Two types of parcels were selected for this study: 1) parcels where conventional tillage (CT) had been practiced for over 7 years and 2) parcels where conservation agriculture or reduced tillage (RT) had been practiced within the last 7 years following prior conventional tillage similar to that in parcel type 1. The CT rotation was traditionally potatoes rotated every 2 years following 2-years of pasture (ryegrass). The RT rotation was potatoes with an oat cover crop previous to potato sowing. In these parcels, oat and potatoes are also rotated with pastures as in CT. RT is distinguished from CT because it left unincorporated oats residues and practiced minimum tillage. The CT systems instead used a Rotovator. Each system was represented by 3 sites. The 6 sites were selected based on similar characteristics such us: 1) landscape position; 2) land use; 3) slope; and 4) rainfall. Thus all sites were located on backslope positions, with linear moderate slopes, under potato-based rotations and the same rainfall regimen.

Two soil pits were dug at each location in May 2007. Soil horizons were identified in each pit, and one soil sample (500 g) was removed from the middle of each of the identified horizons for aggregation and carbon analyses. Thirty-five soil samples were collected in total. In addition, soil samples per horizon were removed using 3 cylinders (2.5 x 2.5 cm.) per horizon to determine the bulk density. The profile was comprised of three horizons with an average thickness of 78 cm (horizon A1, top), 39 cm (A2) and 49 cm (C).

It was found primarily, that conservation tillage in potato-based systems improved in a 7 year period the soil organic matter and carbon content in disturbed soils of the *paramos* of Colombia. The soil carbon concentration (gr C/ Kg soil) in the whole soil profile (to a depth of about 120 cm) and content (t C ha-1) was 29 and 45% higher under conservation tillage than under conventional tillage sites. "C content improvement primarily occurred in the subsoil (A2 horizon) increasing by 177% although in absolute terms most of the C is stored in the top A1 horizon". . This improvement was attributed to the enhancement of soil physical characteristics related with soil water movement and storage such us bulk density, available water content, saturated hydraulic conductivity and mesoporosity. These improvements reflect that conservation tillage, is allowing the rehabilitation of carbon and water-related soil characteristics compared to conventional tillage systems (Table 3 and 4) (Quintero, 2009). In this study the organic matter contained in soil aggregates was determined using ultrasound. The results showed that aggregated organic matter corresponded in most soil samples to 80% or more of the total organic matter in the soil. This means that about 80% of the total organic carbon was in the aggregate pool. Moreover, higher values of %AOM (as a percentage of total OM in the soil) was found in smaller macroaggregates (0.5 -1 mm and 1-2 mm aggregate size fractions) suggesting that in these fractions the C has a slower turnover that the C in bigger macroaggregates (>2 mm). Based on Kong et al. (2005) findings, where increases on C stabilization in the smaller macroaggregates were associated to greater aggregate stability and long-term sequestration, we suggest in the same direction, that the higher AOM and SOM in smaller macroaggregates in our soils is linked to greater C and aggregates stability and in consequence is contributing to long-term C sequestration in the Andes. In addition, increases of AOM may be related to improvement of soil structure. The conservation agriculture curves for OM release using different ultrasound energy levels, had better defined hierarchal steps than did the conventional agriculture curves. Since well defined steps indicate well developed structure, we suggest that conservation agriculture in these Andean soils also improves structure. Methodological details are explained in Quintero (2009).

Table 3. Comparison of soil characteristics across soil treatments (Source: Quintero, 2009)

	Bulk density (g cm^{-3})♠	Sat. Hydr Conduct. (cm h^{-1})♦	Porosity (%)♦	Macropores (%)♦	Mesopores (%)♦	Micropores (%)♦	SOM (g/Kg) ♦	SOC (g/Kg) ♠	AWC (%)♦
Conservation agriculture	0.81 (a)*	18.1 (a)	66.1 (a)	21.5 (a)	9.5 (a)	35.8 (a)	220 (a)	150 (a)	9.56 (a)
Conventional agriculture	0.96 (b)	8.0 (b)	62.6 (a)	19.7 (a)	6.6 (b)	35.8 (a)	170 (b)	100 (b)	6.67(b)

*Within a soil characteristic, the means followed by different letters are statistically different at $p < 0.05$ and show the effect of horizon. ♠ Significantly different at $p<0.1$. ♦ Significantly different at $p<0.05$

Table 4. Effects of soil horizon and treatment on soil carbon content (Source: Quintero, 2009)

Treatment	C (t/ha)*
Conservation tillage	891(a)
Conventional tillage	612(b)

* Mean values with different letter inside the same column are significantly different at $P<0.1$

From the economic perspective, when the ECOSAUT model was run to identify an optimal solution –the one that maximizes net revenues in a hectare giving the two treatments as the only land use alternatives, the conservation tillage rotation was the optimal solution. The 7-year cumulative net revenues for the assessed rotations indicated that conservation tillage rotation increased the net revenues by 17% compared to the conventional tillage rotation. This increment is due to particularly the improvement on potato income in 23% when conservation tillage is practiced (Table 5). This improvement was high enough to compensate the additional investment required in the conservation tillage rotation that is the production costs of incorporating oat as a cover crop in the rotation ($337 ha-1 yr-1). A greater net return from potato cropping using conservation tillage practices was related to a reduction of production costs by 11% and to an increment of potato productivity by 10%. Lower production costs were due mainly to a reduction in fertilizers and machinery costs rather than in a substantial reduction in the use of workdays which instead was similar in both, conservation and conventional tillage (table 6).

Table 5. Economic benefits from conventional and conservation tillage in potato-based systems in Fuquene watershed (Colombia)*.(Source: Quintero, 2009)

Characteristic	Rotations Conventional tillage	Conservation tillage
Net income (US$)	13,092	15,280
Marginal income		2,188
Average annual income (US$)	1.870	2,183
Marginal annual income		313
Income from potato (US$)	11,689	14,341
Marginal potato income		2,652
Income from milk	4,119	4,119
Marginal milk income		0
Income from meat	105	105
Marginal meat income		0
Use of workdays	564	554
Marginal change (%)		-2

* Estimations made in a hectare basis and for a 7-yr period and discounted by a 5% rate

Table 6. Annual average values for potato production under two tillage systems (Source: Quintero, 2009)

Characteristic	Conventional tillage	Conservation tillage	Change (%)
Production costs (US$ ha^{-1})*	2077	1857	-11
Labor costs ($US ha^{-1})	909	906	0
Potato productivity (kg ha^{-1})	26937	29625	10
Potato sale price (US$ kg^{-1})	0.217	0.217	0
Use of workdays (ha^{-1})	126	122	-3

* Without including labor costs

Altomayo watershed

For the Rumiyacu and Mishquiyacu micro-watersheds, located in the Altomayo watershed, 7 subwatersheds and 22 HRUs for the Mishquiyacu watershed, and 6 subwatersheds and 28 HRUs for Rumiyacu were determined. For the modeled period, 1999–2005, during the dry months when some potable water was drawn from the Rumiyacu River for consumption in Moyobamba, the latter did not increase sediments to total flow. This indicates that most sediment in the water treated by EPS comes from the Mishquiyacu watershed (Quintero et al. 2005). With respect to the performance of the simulation, we obtained a Nash-Sutcliffe coefficient[1] of only 0.03: comparison of observed and simulated time series demonstrates that during days of high rainfall (>100 ml), observed stream flow is systematically underestimated; regressing the latter on the former yields an R2 of 93.75%. This is probably explained by limitations in the local measurement technique and frequency (e.g. stream stage), resulting in underestimated observed data. Nevertheless, the minimum and intermediate stream flows are better predicted: R2 is 96.5 and 97% in the two cases, without systematic biases. In general, the simulated time series fits quite well with the observed one, which is important for determining the HRU with higher sediment yields. The sedimentation analysis was thus focused on Mishquiyacu, where 8 HRUs showed particularly high sediments per hectare. They contained slash-and-burn systems or abandoned areas occupying 23.1 ha, and accounting for an estimated 27% of total sediments in the watershed (Table 7).

Table 7. Prioritized hydrologic response units in the Mishquiyacu watershed (Peru) under the "business as usual" scenario (source: Quintero et al. 2009)

HRU code #	Area size (ha)	Sediments over 7 years		% contribution to total sediments produced in micro watershed
		(t ha^{-1})	(t)	
18	9.1	903	8,217	16.5
02	5.8	500	2,902	5.8
06	0.9	396	356	0.7
09	0.9	323	291	0.6
12	1.2	261	313	0.6
22	2.2	374	823	1.7
03	1.9	292	555	1.1
19	1.1	239	263	0.5
Total	**23.1**	**3,289**	**13,720**	**27.6**

[1] Nash–Sutcliffe efficiencies can range from −∞ to 1. An efficiency of 1 corresponds to a perfect match of modeled discharge to the observed data. An efficiency of 0 indicates that the model predictions are as accurate as the mean of the observed data, whereas an efficiency less than zero occurs when the observed mean is a better predictor than the model

For these HRUs, SWAT simulations showed that, depending on model parameters chosen, the establishment of live barriers, forest plantations, and shade-grown coffee each potentially could about halve sediments", compared to "business as usual". In terms of total streamflow (although this is not the main externality of interest for Moyobamba and results are only shown as additional information), shade-grown coffee would reduce quantities by 11% and forest plantations by 14%, while live barriers would not have any impact (Table 8).

Table 8.Integrating environmental and socioeconomic assessments of land-use scenarios in Mishciyacu watershed, Peru (source: Quintero et al. 2009)

Indicator	Land use system			
	Traditional ("business as usual")[a]	Traditional[a] with live barriers	Shade-grown coffee planted on pastures	Forest planted on pastures
NPV (US$), 10 year horizon[b]	12,949	9,668	32,057	967
Marginal income	n.a.	-3,281	19,108	-11,982
Initial cash investment (US$)	9	13	176	470
Sediments (t ha^{-1})	21,247	10,623	11,766	10,620
Marginal sediments (%) [c]	n.a.	-50	-44	-50
Water production (m^3)	2,707,711	2,707,711	2,395,627	2,334,858
Marginal change (%) [c]	n.a.	0	-11	-14
Use of work days	5,682	5,807	10,071	5,266
Marginal change [c]	n.a.	125	4,389	-416

[a] Burning-maize-pastures land-use cycle
[b] Includes labor cost. Discount rate = 15%[2]. Converted from Peruvian *soles*; exchange rate 1 US$ = 3 soles (January 2009)
[c] Vis-à-vis baseline of traditional slash and burn land-use sequence
n.a. – not applicable

We used ECOSAUT to calculate the NPV (discount rate of 15%, 10 years) for the different land-use alternatives. Introducing shade-grown coffee would require significant initial investments, but still increase NPV by 91%, compared to the traditional slash-and-burn system. In contrast, forest timber plantations would reduce NPV by 62% and live barriers by 11%, if no compensations are being paid to farmers. Finally, we calculated the cost of reducing one ton of sediments, using the marginal NPV and including labor costs (Table 9). The results show that the live barriers alternative is cheapest to install (US$0.36 t^{-1}). The higher cost of reducing sedimentation with shade coffee and forest plantations (US$1.16 and 1.10 t^{-1}, respectively) is due to their higher investment costs. However, live barriers had negative income effects as it imposes additional costs to the traditional system without an increase on income, so farmers are unlikely to adopt them unless they receive compensation. Instead, shade coffee systems seem to provide the best trade-off between environmental and economic benefits, since they both increase environmental services and medium-term incomes. Yet, high initial investment costs may mean that farmers may only be willing to change if they receive PES in the form of significant transitory payments or subsidized, contingent credits.

[2] A discount rate of 15% is likely to be much more representative than the rate of 5% used in the Fuquene case due to the socioeconomic conditions of small farmers in these countries

Table 9. Unit costs of reducing sediment yields under different land-use scenarios in Mishquiyacu watershed, Peru (source: Quintero et al. 2005)

Parameter	Current scenario, with live barriers	Shade-grown coffee	Forest plantation
Cost of reducing one ton of sediments (US$/t)	0.36	1.16	1.10
Cost of reducing erosion on one hectare of land (US$/ha)	16.6	47.4	51

Our hydrological results are in line with what the literature reports: there is little doubt that both annual water yields and particularly surface erosion from forests are lower than for non-forested tropical areas (Bruijnzeel et al. 2004). This is basically explained by an increase on water loss by evapotranspiration once forests are planted. It is worth noting, that although water yields are lower with tropical forests, the regulation of water flows may improve with it as moderate pick flows can be reduced ad base flows can be increased as a result of improving soil water infiltration and water holding capacity. Converting the 23.1 ha of critical slash-and-burn areas to shade-grown coffee would provide a 'win-win' of both significantly more sediment retention and higher farmer incomes. However, probably due to farm household liquidity shortages, as the main obstacle, low-return slash-and-burn systems still dominate the watershed. The initial capital investment needed to establish shade-grown coffee is US$176 ha^{-1}. In contrast, the traditional burning-maize-pastures system requires only $9 ha^{-1} in capital costs for seeds. The lack of financial infrastructure (and possibly of technical assistance) may thus constrain the adoption of shade-grown coffee systems. The favored strategy of EPS and the Municipality is to buy environmental services while also improving the socioeconomic conditions of upstream farmers. For setting up live barriers on land dedicated to maize and pastures, the marginal cost of reducing erosion is US$0.36 t^{-1}, i.e. $16.6 ha^{-1} $year^{-1}$ -- to be paid every year, since the barriers need yearly maintenance. In comparison, to encourage farmers to establish shade-grown coffee would seemingly require only a two-year subsidy of US$269 ha^{-1} $year^{-1}$; for the following years, profits from shade-grown coffee exceed those from annual cropping. Taking into account that priority areas only cover 23.1 ha, and that changing their use could potentially cut sediments by 18%, this is the preferred alternative for stakeholders in Moyobamba. It is worth to highlight that shaded coffee was an alternative suggested by local stakeholders who perceived it as a promissory economic activity due to the increasing national demand for the high quality coffee of this region. Subsidized loans for shade–coffee adoption are thus now discussed, which would seemingly be cheaper than a permanent PES scheme. The resources could probably be collected directly from the Moyobamba water users whose stated willingness to pay is US$1.3 $family^{-1}$ $month^{-1}$ (Nowick 2005). With 7136 paying water users, the necessary resources for promoting a change in the land use might be collected in just two months.

Jequetepeque watershed

The main environmental externality affecting the water quality in the Jequetepeque River watershed is the sedimentation is caused by the advanced deforestation of the watershed and the current conventional agricultural practices. The hydrological analysis for the whole watershed showed that in average 1’823.703 tons of sediments are produced annually. The erosion process in the upper and middle parts of the watershed is causing the accelerated siltation of the Gallito Ciego reservoir, which is essential for irrigated fields downstream, flooding control and production of hydropower. With respect to water regulation, the hydrological analysis showed a high monthly and annual variation of streamflows. This irregularity in the streamflow availability affects downstream agricultural production, especially rice production which is the main agricultural activity in the region. The actors indicated that extreme climatic events such as drought and extreme high rainfall events are causes of main concern.

SWAT was capable of simulating water and sediment yields under the current and proposed land use scenarios. With respect to the simulation performance, the simulated flows fit well with measured ones (figure 3) although in some occasions the simulated flows are lower. This may be related to lack of information regarding aquifers and its contribution to the water flow. However, a good fit of simulated vs. measured data still permitted to the identification of those areas with high impact on water and sediment yield.

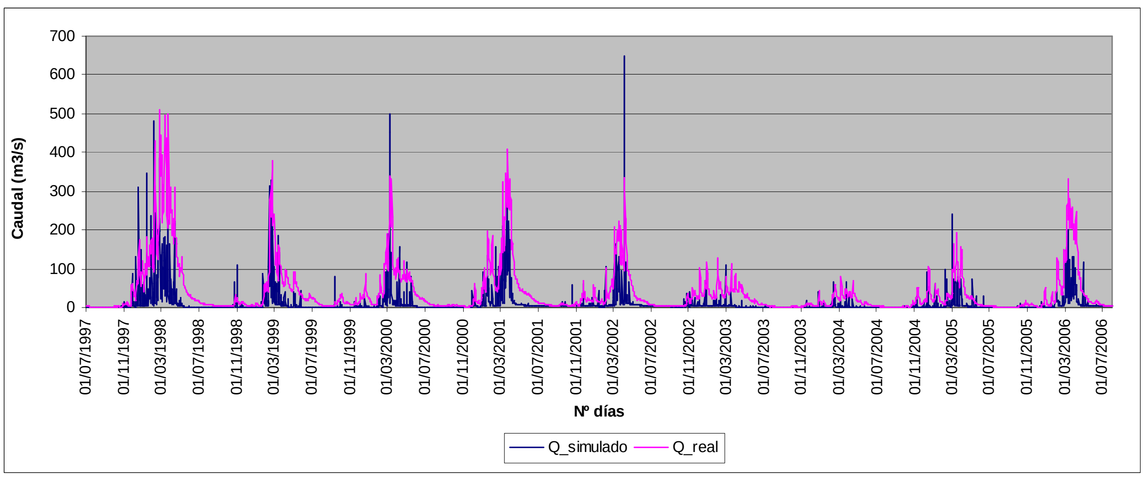

Figure 3. Jequetepeque water flows: Simulated vs. measured.

The SWAT analysis –based on calibrated simulated flows, showed that 60% of the time, the average streamflow of the Jequetepeque river is higher than 2.1 m^3s^{-1}. This model permitted to determine 441 HRUs distributed in 38 sub-watersheds of which seven (Asuncion, Pallac, Chausis, Contumaza, Huacraruco, Choten, Llapa/Yanahuanga) are producing the highest amounts of sediments (Table 10). In these sub-watershed 10 HRUs were prioritized on the basis of their contribution of sediments to the streamflows (Table 11, figure 4 and 5)

Table 10. Degradation* in the prioritized sub-watersheds of the Jequetepeque River watershed (Peru) (Source: Lopez and Giron 2007)

Sub-watershed	Name	Area (ha)	% Watershed	% Degraded	Degraded area (ha)
4	Llapa/Yanahuanga	19898	6.02	12.94	23954.29
9	Pallac	23917	7.24	19.94	33069.63
22	Contumaza	18435.8	5.58	56.55	54627.31
29	Chausis	20926.2	6.33	67.06	59441.4
31	Choten	3481.9	1.05	45.39	24540.4
33	Huacraruco	14167.1	4.29	36.14	56884.65
36	Asuncion	8050.1	2.44	20.86	38332.31

*Lands without land cover were assumed to be degraded or under degradation process

Table 11. HRUs with the highest sediment yields in the Jequetepeque River watershed (Peru) (Source: Lopez and Giron 2007)

Sub-watershed	Name	Soil	Area (ha)	Surface runoff. (mm)	Sedim Yield. (t/ha)	Sediments (t)	Current land use
36	Asuncion	H	1679.4	303.91	22.83	38332.31	Crops of template zones
9	Pallac	T	4769.2	220.29	6.93	33069.63	Crops of cold zones
29	Chausis	L	11606.5	106.97	2.74	31778.6	Annual pastures
22	Contumaza	L	2958	179.25	10.17	30088.78	Crops of template zones
33	Huacraruco	H	1210.3	331.83	24.71	29907.72	Crops of cold zones
29	Chausis	L	2427.2	186.56	11.4	27662.8	Crops of template zones
33	Huacraruco	L	3909.7	212.78	6.9	26976.93	Perennial pastures
31	Choten	L	1580.6	212.23	15.53	24540.4	Perennial pastures
22	Contumaza	L	7467.6	106.96	3.29	24538.53	Annual pastures
4	Llapa/Yanahuanga	T	2574.9	386.42	9.3	23954.29	Crops of cold zones

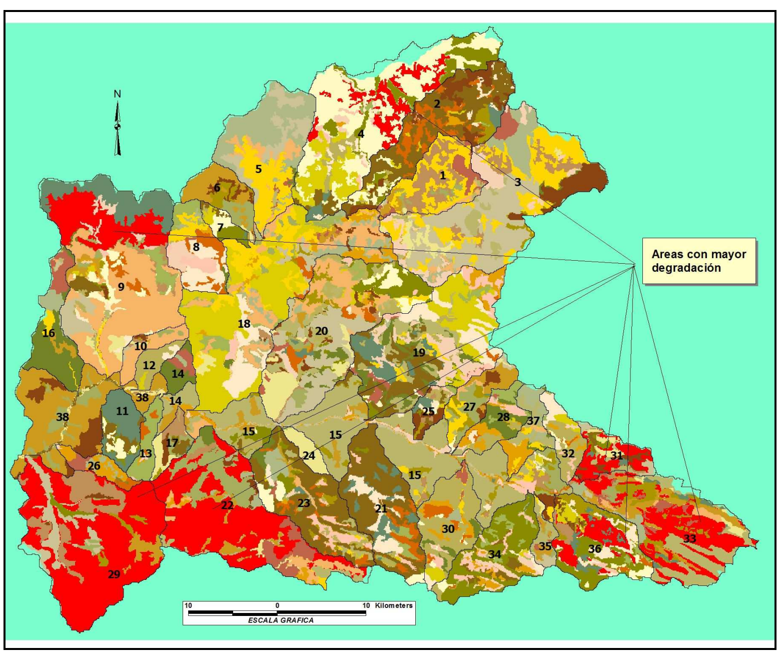

Figure 4. HRUs prioritized on the basis of highest production of sediments (highlighted in red). (Source: Lopez and Giron 2007)

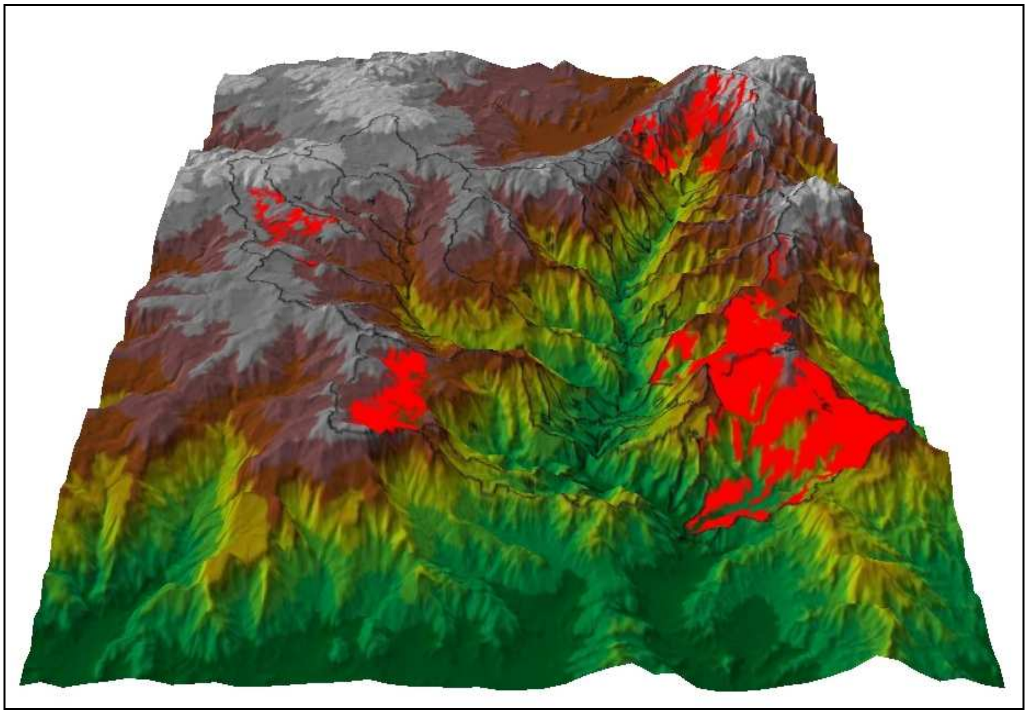

Figure 5. HRUs prioritized on the basis of highest production of sediments (highlighted in red), (Source: Lopez and Giron 2007)

In the prioritized areas, 3320 households represent 15220 people (in 2001) and are distributed among several small towns (figure 6). For these areas, 4 different land use change scenarios were simulated in order to predict how sediment yield may be modified. The four scenarios were: reforestation, deforestation of remaining forests, agroforestry systems and agriculture with contour strips. The simulation results showed that reforestation, agroforestry systems and management practices in the agricultural systems to control erosion (contour strips) reduce the production of sediments in the prioritized areas compared to the current land use. Specially, reforestation and agroforestry systems would reduce the sediments by 41 and 54%, respectively (Table 12).

Table 12. Production of sediments under different land use/management scenarios in the prioritized HRUs (source: Lopez and Giron 2007)

HRU No.	Sub-watershed	Current land use	Reforestation	Agroforestry	Deforestation	Contour strips in cropping areas
		Sediment yield (Ton)				
36	Asuncion	38332.31	18747.14	16830.95	39464.22	28198.81
9	Pallac	33069.63	11889.62	8961.33	34428.85	20970.17
29	Chausis	31778.6	29666.21	22458.58	29283.20	30908.11
22	Contumaza	30088.78	14695.34	14254.6	28769.51	20901.23
33	Huacraruco	29907.72	14313.01	10413.42	29819.37	18741.50
29	Chausis	27662.8	14568.05	12881.15	27592.41	20206.44
33	Huacraruco	26976.93	18100.18	12174.81	27794.06	26675.88
31	Choten	24540.4	16193.52	11889.27	23886.03	23923.96
22	Contumaza	24538.53	24583.34	17996.92	24560.94	24762.56
4	Llapa/Yanahuanga	23954.29	8046.56	6051.02	24131.96	13662.42
	Total	**290849.99**	**170802.98**	**133912.03**	**289730.55**	**228951.08**
	% reduction		**41.27**	**53.96**	**3.85**	**21.28**

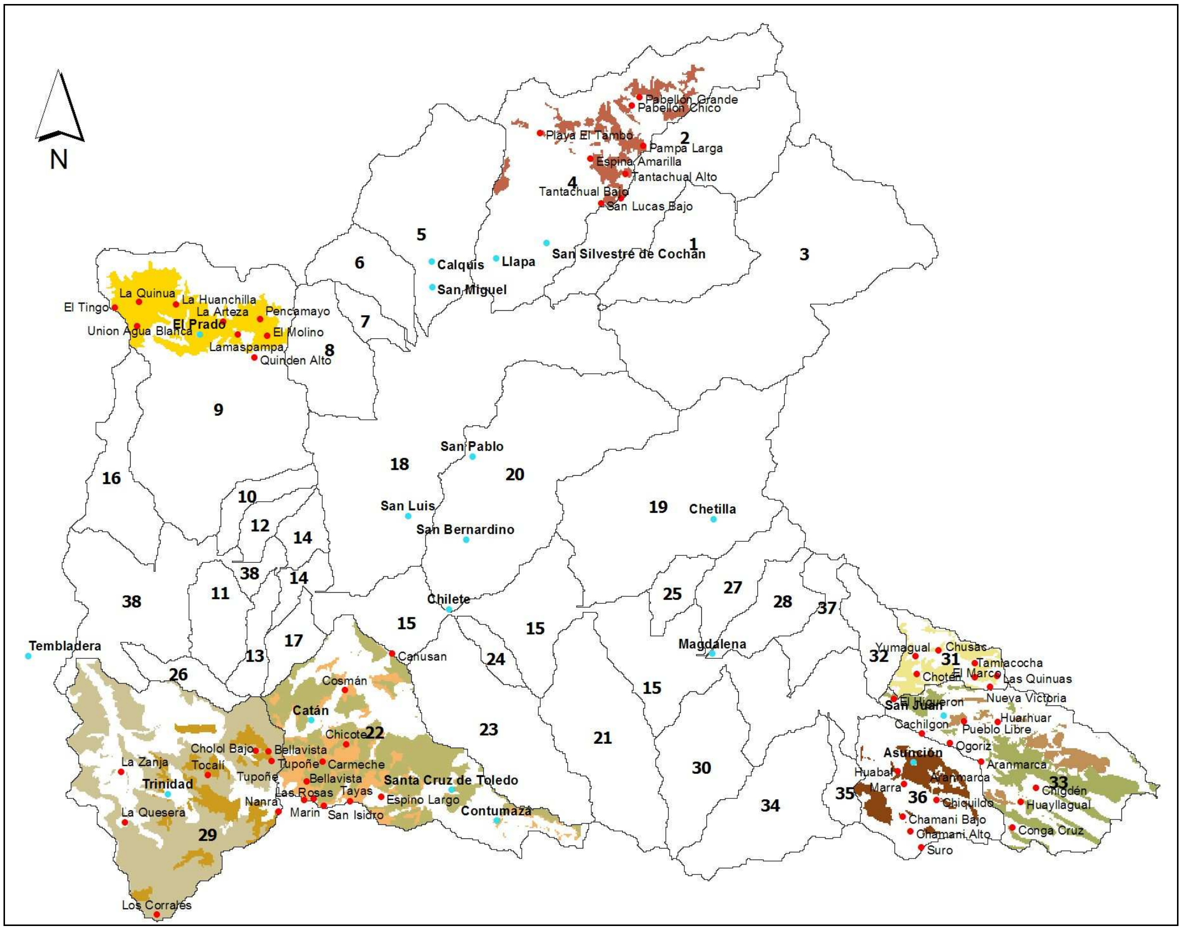

Figure 6. Location of small towns in prioritized areas in the watershed.

For the reforestation and agroforestry systems, the costs and benefits of their implementation (table 13) were estimated for reforestation of 250 ha, 450 ha under agroforestry systems and 110 ha under silvopastoral systems respectively.

Table 13. Costs and benefits of different land use alternatives in selected areas of the Jequetepeque watershed ($Soles ha-1) (Soles = Peruvian currency)

	Agroforestry	Silvopastoral systems	Reforestation
Costs			
Implementation	3635	1229	1547
Maintainance	177	1110	120
Benefits (income)			
Year 2	642	890	-120
Year 6	2089	2890	-120
Year 10	2089	4290	27580

On the other hand, a willingness to pay analysis (Soncco 2005) using a referendum-type question and a parametric method, found that 52% of the potential beneficiaries are willing to pay to conserve and provide better watershed services. Their willingness to pay was US$3.64 ($Soles 11.83) per household per month. Because not all beneficiaries indicated willingness to pay (43% manifested no willingness to pay due to their unfavorable economic situation), the project proposed to negotiate the implementation of the suggested land use changes in 10% of the selected area as a means to start up the mechanism and as a strategy to attract new beneficiaries to contribute to the mechanism as it advances. Also this mechanism, by not financing 100% of the costs may serve to test to what extend a partial incentive to cover these costs in order to promote the desired land use change is necessary . Specifically the proposal was to start financing 50% of the investment costs in 10% of the proposed area. The total required funds to start this payment scheme are showed in table 14 (Moreno & Renner 2007)

Table 14. Proposed payment scheme in the Jequetepeque watershed

	Area (10% of the potential area)	Implementation costs (50% of the total cost) ($Soles ha^{-1})	Total ($Soles)
Llapa subwatershed			
Agroforestry	20	1818	36360
Silvolpastoral systems	-	-	-
Reforestation	10	774	7740
Pallac subwatershed			
Agroforestry	15	1818	27270
Silvolpastoral systems	5	615	3075
Reforestation	10	774	7740
Asuncion subwatershed			
Agroforestry	10	1818	18180
Silvolpastoral systems	3	615	1845
Reforestation	5	774	3870

Tunari microwatersheds: Pajcha, Pintu Mayu and Khora Tiquipaya

Natural disasters associated to flooding events in the Cochabamba Valley (Bolivia) have historically implied high costs and losses to the Cochabamba population and the State. One of the main factors that increases the flooding risk level is the agriculture frontier expansion onto the microwatersheds of the Tunari Mountains that surround the city. Also the expansion of urban centers without any planning is affecting the hydrological dynamics in these microwatersheds. In this context, PROMIC (Integrated Watershed Management Program) initiated many years ago a project to promote better management practices in agricultural lands and hydraulic infrastructure activities in order to improve streamflow regulation to reduce maximum flows and retain it during extreme rainfall events. The management practices include: slow formation terraces using live barriers or rocks, organic manures, crop rotation and permanent soil cover (PROMIC 2007a)

Our project through PROMIC and the Universidad Mayor de San Simon, conducted hydrological modeling to simulate the effect that these practices have had on maximum streamflow and the retention of water flows. This analysis was conducted with other hydrological models different that the one used in the other studied watersheds (ie. SWAT). In this case, the models used were LISEM, Muskingun-Cunge and Flo2d, with which hydrograms were built for scenarios with and without project respectively (project in this context refers to the practices promoted by PROMIC to improve water flow regulation). The hydrograms show how maximum streamflow (the peak in the curves) are modified by the implementation of project activities for each of the three rivers studied.

The results of the simulation showed that the project activities would modify significantly the maximum streamflow levels for the modeled microwatersheds. These practices reduce the maximum streamflows in 18, 15.7 and 24.9% in the Pajcha, Pintu Mayu and Khora Tiquipaya microwatersheds, respectively (figures 7 – 12). On the other hand, the extent of flooded areas was modeled indicating a reduction of 60, 15.7 and 36% in maximum streamflow during extreme rainfall events in the Pajcha, Pintu Mayu and Khora Tiquipaya microwatersheds, respectively, when the project activities are implemented (PROMIC 2007b).

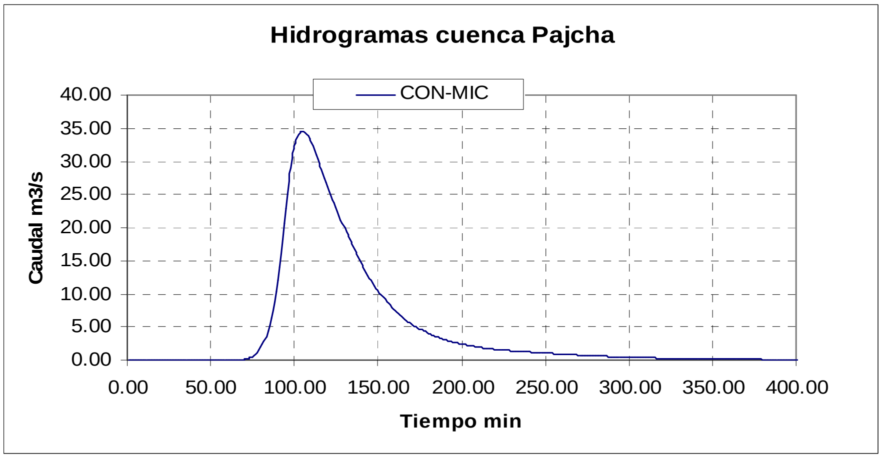

Figure 7. **Hydrogram for the Pajcha River microwatershed: With-project scenario**

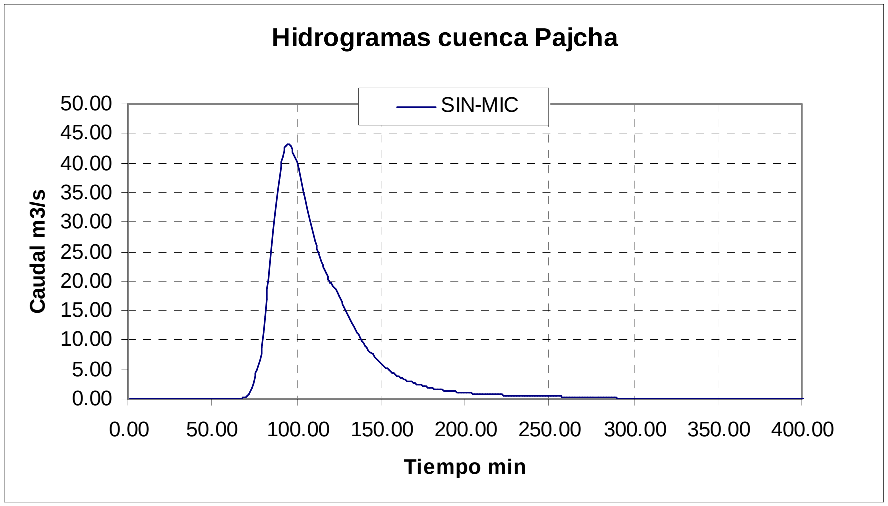

Figure 8. **Hydrogram for the Pajcha River microwatershed: Without-project scenario**

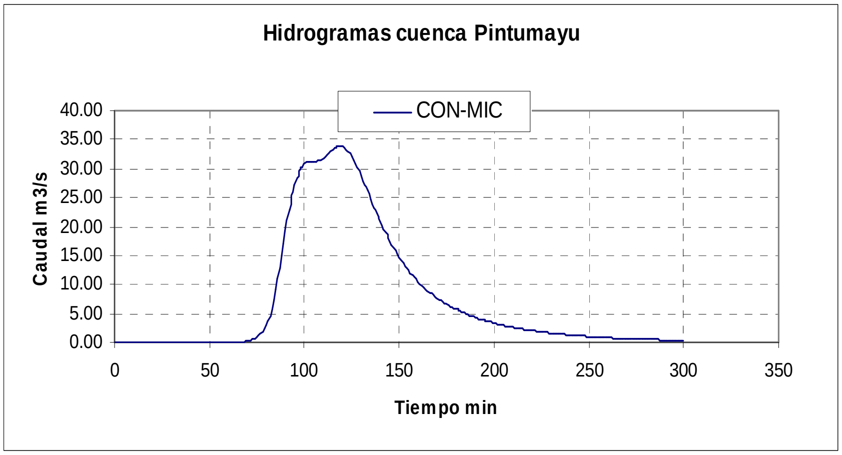

Figure 9. Hydrogram for the Pintu Mayu River microwatershed: With-project scenario

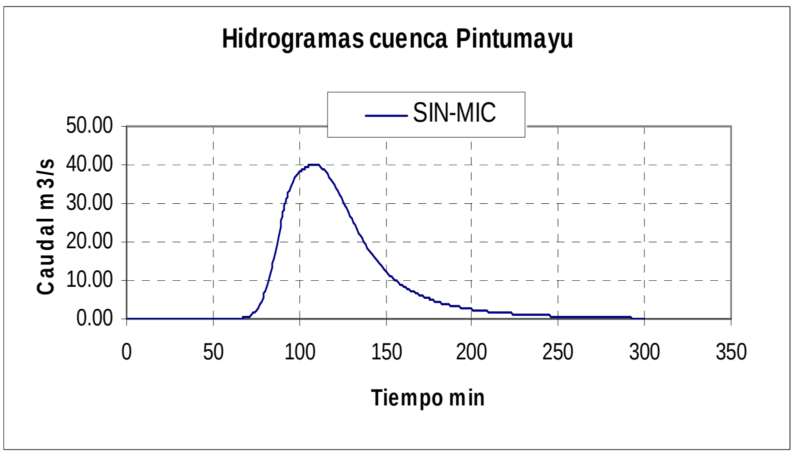

Figure 10. Hydrogram for the Pintu Mayu River microwatershed: Without-project scenario

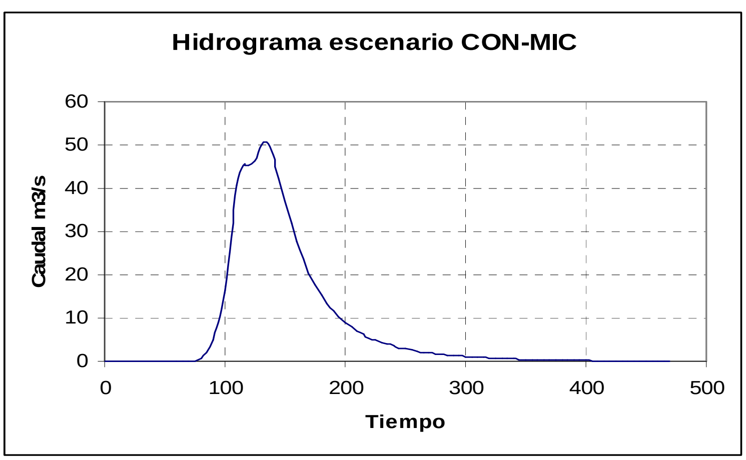

Figure 11. Hydrogram for the Khora River microwatershed: With-project scenario

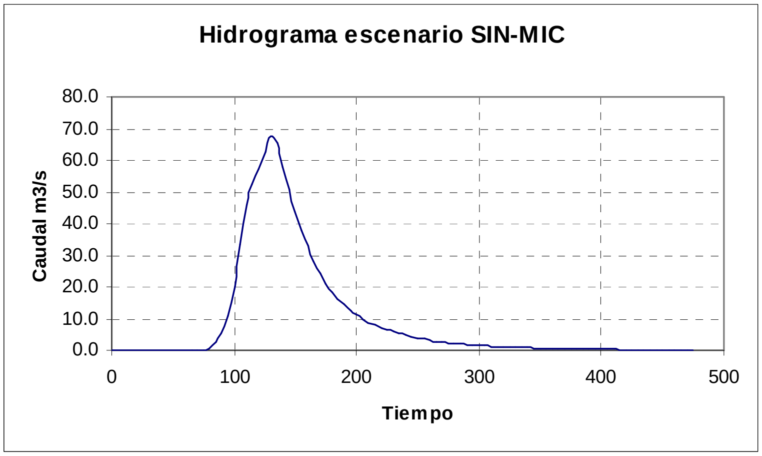

Figure 12. Hydrogram for the Khora River microwatershed: Without-project scenario

From the economic standpoint, a cost-benefit analysis was conducted to understand the benefits that these management practices imply for producers located in the upper and lower part of the watershed. In the upper part, farmers grow potato for self-consumption and had reported and increment in the productivity once the management practices promoted by PROMIC were implemented. Potato growers of the lower part sell most of the produce in the local market and their systems are more intensive, using agrochemicals, herbicides, etc. These producers have abandoned many of the practices promoted by PROMIC and the only ones that are maintained are the terraces constructed with rock walls. During the surveys they also reported an increment in the productivity but this may be a result of the intensive use of agrochemicals. In the lower parts of the watershed the cultivation of flowers is also very important and complements the production of potato. The farmers have reported increments in the productivity after the implementation of practices promoted by PROMIC. In table 15, a summary is shown of the cost-benefit ratio for the different farmers in the watersheds (PROMIC, 2007a).

Table 15. Cost-benefit relation for the main agricultural products in the microwatersheds with and without-project activities.

Product	Location in the watershed	Without project activities	With project activities	Difference
Potato	Upper	1.09	0.78	-0.30
Potato	Lower	1.26	1.78	0.51
Flowers (reyna)	Lower	1.50	1.68	0.18
Flowers (clavel)	Lower	1.44	1.63	0.19

Ambato watershed

The upper parts of the Ambato watershed are essential for supplying water to downstream areas including urban centers and agricultural fields. These upper parts are paramos –alpine grasslands that have an important role in the storage of water and regulation of streamflows, due to their particular soil and climatic characteristics. This important role has been recognized by the provincial government and as such, the construction of two reservoirs has been planned for collecting the water produced in upper catchments and expand the irrigated agricultural areas downstream. The reservoirs are the Mulacorral and the Chiquiurcu with a storage capacity of 4.8 millions of cubic meters that may benefit new agricultural areas (about 1670 ha) in the lowlands of the Ambato watershed. The Mulacorral reservoir is already built and the Chiquiurco is in the contracting process.

The project team conducted an analysis to evaluate the potential of the corresponding watersheds to fill up the reservoirs throughout the year and to estimate the private and social benefits (including a competitiveness analysis of the production systems and the multiplier effects of generating additional jobs and income) derived from the expansion of the agricultural frontier downstream. The results have been used by the Tungurahua provincial government in order to propose the most appropriate mechanisms to recover the reservoirs investment costs by charging the beneficiaries.

To do this, the SWAT model was used to determine the monthly water yield produced by the watersheds. The simulation results fit well with measured data with a correlation of simulated vs. measured data of 58% (figure 13). The results showed that it is only possible to maintain the maximum storage levels of the reservoirs during dry season if 100% of the streamflows during the rainy season is used for filling up the reservoir. This implies that not any streamflow is left for aqueducts and for maintaining the ecologic functions of the rivers. Under a scenario where only 30% of the streamflow above the mean values is used for filling up the reservoirs, it was found that it may be not possible to reach the maximum capacity of storage reservoirs during the dry season (figures 14 and 15) (Estrada et al. 2009).

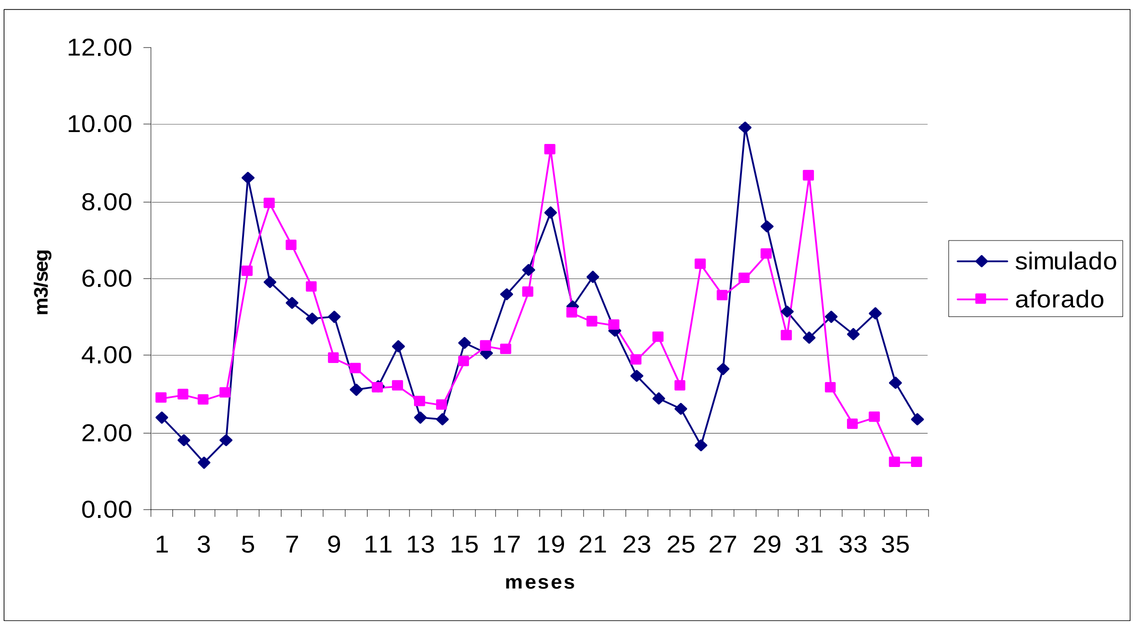

Figure 13. Available water for filling up the Mulacorral reservoir.

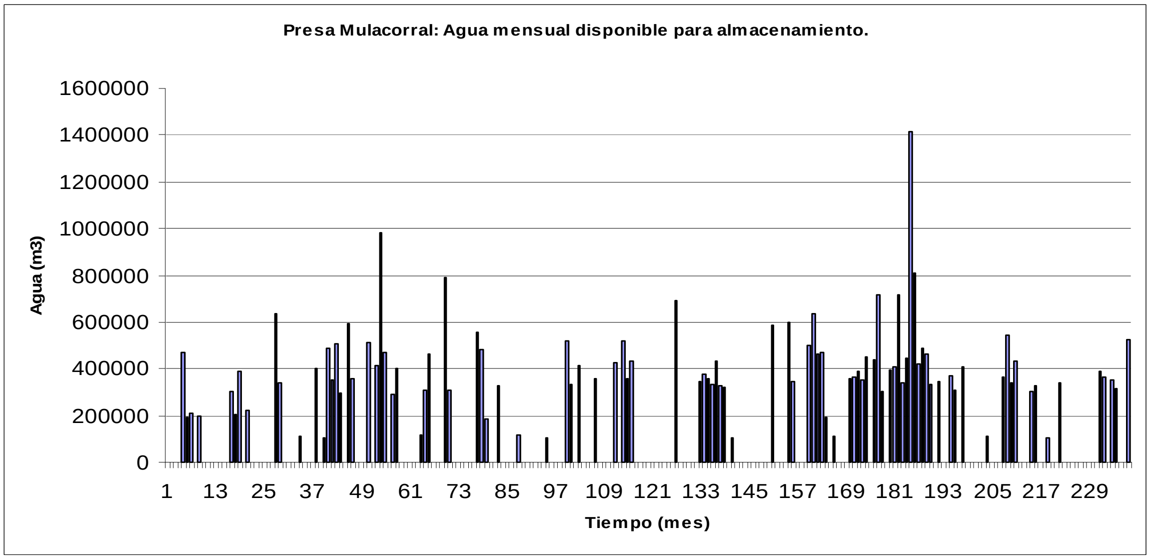

Figure 14. Available water for filling up the Mulacorral reservoir.

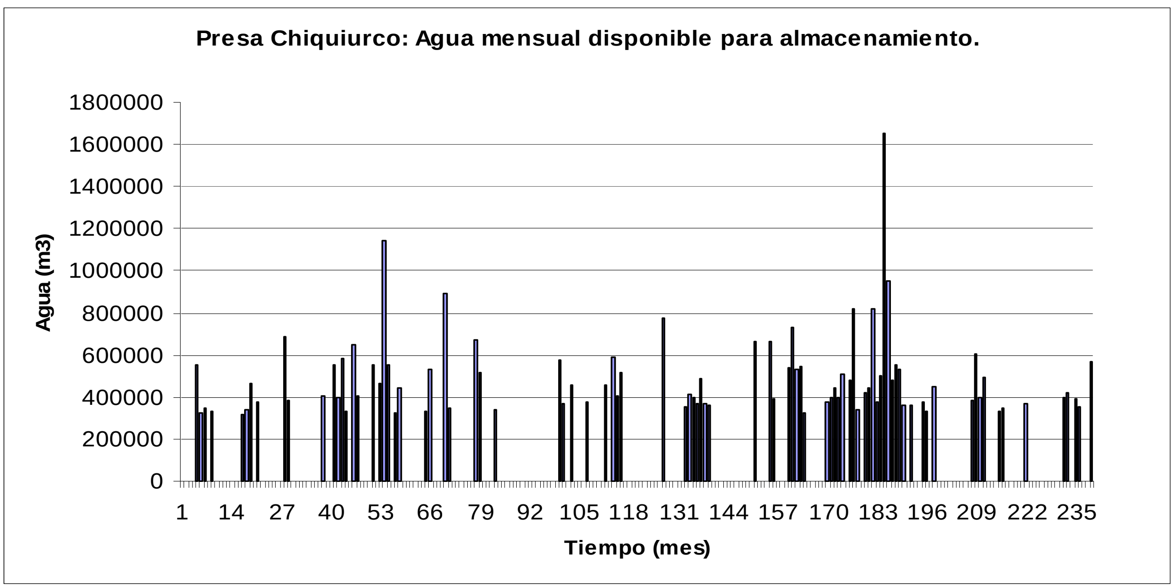

Figure 15. Available water for filling up the Chiquiurco reservoir.

Apart from these simulated results, the economic analysis was conducted for the most optimistic scenario where it was assumed that it will be possible to use the maximum storage capacity of the reservoirs for adding irrigated fields to the downstream agricultural areas. In figure 16, it is shown how the benefits are distributed if the agricultural area is expanded as expected. The social benefits include the multiplier effects analysis.

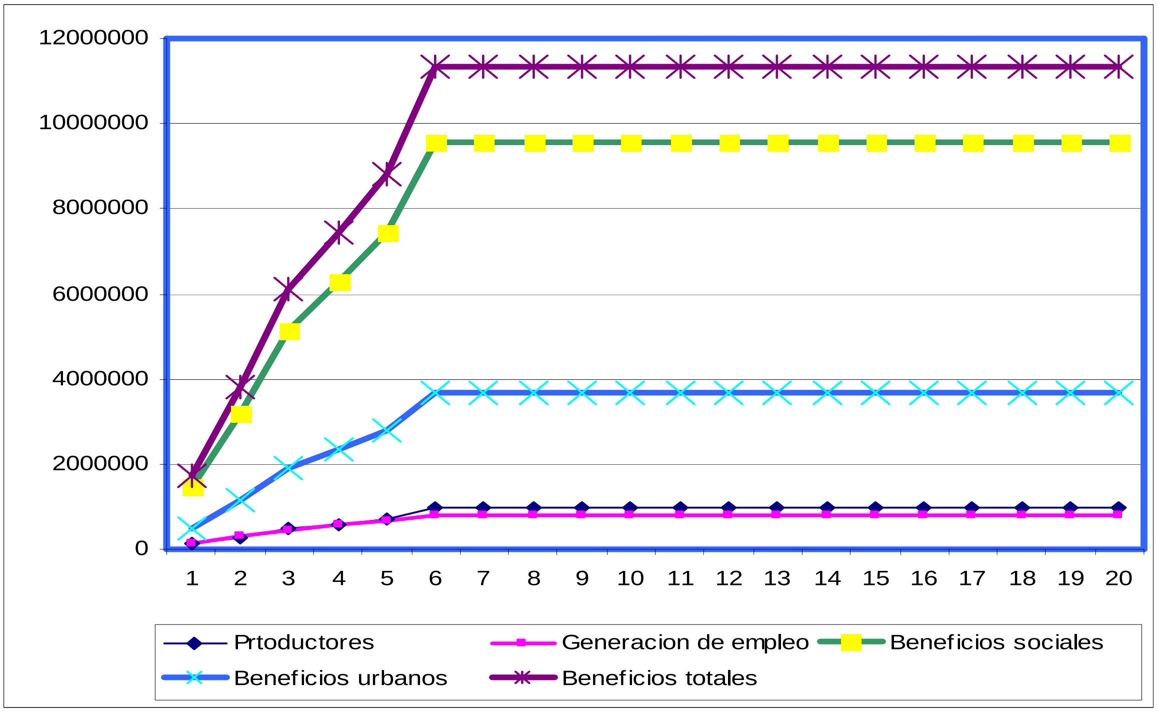

Figure 16. Distribution of benefits derived from the construction and operation of the Mulacorrales and Chiquiurco reservoirs (USD per year)

With respect to the profitability of these infrastructure projects, the IRR is 4% if only the agricultural-related benefits are considered. However if the benefits for urban water consumers are accounted due to the increment of water during dry season, the IRR is higher (9%). Now, if the overall social benefits are taken into account, the social profitability of the project can be 31%. In figure 17, it is shown that benefits for the society represent 94% of the total benefits generated by the project (Estrada et al. 2009). These results contradict the initial provincial government proposal to recover investment costs where the producers are assumed to be the ones that may capture the highest amounts of benefits. However this analysis showed that water consumers and the society in general are the sectors that will capture more benefits and as such should be involved in any scheme to recover the investment cost and eventually to compensate upper catchments farmers who may be affected by the reduction of the streamflow when this is used to filling up the reservoirs to their maximum capacity.

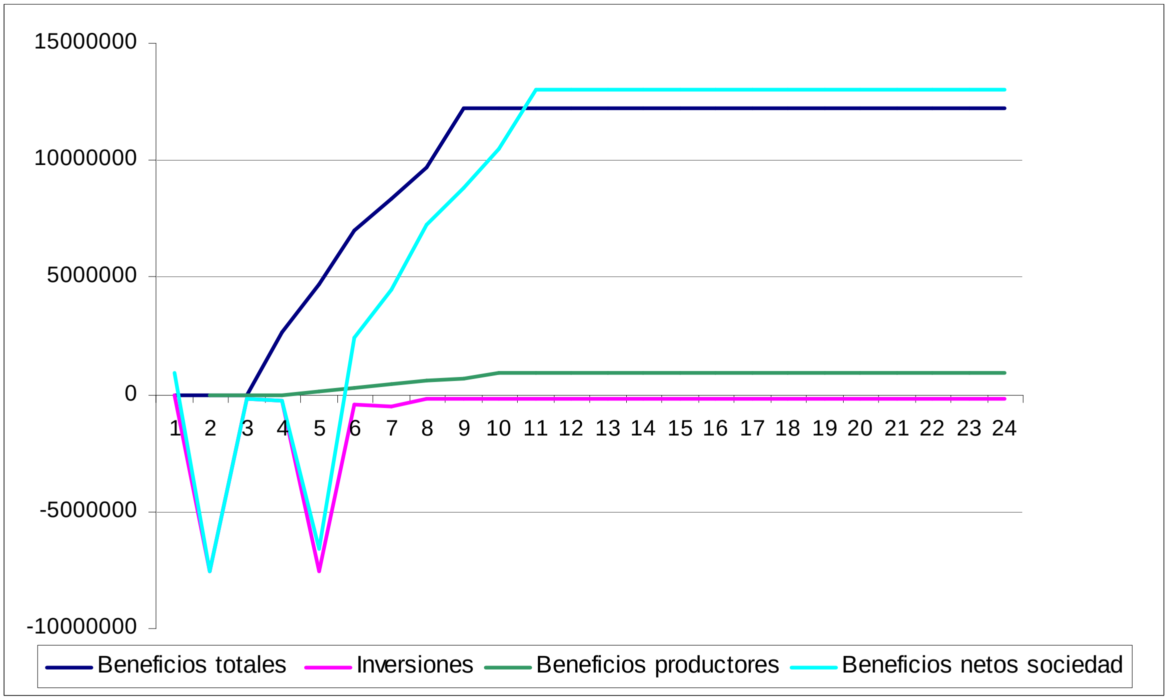

Figure 17. Distribution of investments and benefits derived from the construction and operation of the reservoirs (USD per year)

Poverty profiles in the studied Andean watersheds

The poverty profiles are described based on a classification of the watersheds by climatic conditions: dry, semi-humid and humid . The poverty profiles results are summarized as follows:

1. Dry Andean watersheds (microwatersheds located in the Tunari mountains of Cochabamba, Bolivia). These microwatersheds are located between 2500 and 5000 m altitude, with steep slopes and dry conditions (500-700 mm yr^{-1}). There is an inverse relationship between the altitude and the precipitation.

The proportion of poor households varies by community ranging from 12 to 32% of the total households. There is a direct relationship between the altitude and the poverty levels. This is explained by the fact that in 95% of the poor households its members are farmers or work in other agricultural activities located in areas above the 3600 m altitude where there is a high frequency of frost events and productivity levels are low . This reduces the economic retribution to the workday of these people. In addition, 68% of the poor households owned less than 0.25 ha contrasting with the wealthiest households, where 74% of them own companies, stores or at least have a technical profession (e.g. builder) (Westermann and Arevalo 2008).

2. Semi-humid watersheds located away of big cities (Ambato watershed – Ecuador and Jequetepeque watershed – Peru)

The poverty profiles in these two watersheds are similar. The poorest households correspond to 25 and 28% of the total households respectively. In Ambato, any of these families have more than 4 cows, its members are day labourers who 60% of their time are unemployed. Their income is low and generated through activities inside the watershed. The productive capacity of their lands is similar to that found in lands of non-poor households but the area is smaller. Thus, 90% of the poor households do not own land or have less than 0.4 ha, while 70% of the non-poor households have lands larger than 0.4 ha. In 64% of the poor households the lands are never left under fallow while in only 34% of the non- poor households, their lands are permanently cultivated. The access to irrigation is similar among all households and the water availability throughout the year is not related with the poverty levels.

In 26% of the poor households the woman plays a role as the household's head and in 48% of the poor households the children between 13 and 18 years old do not go to school. Instead, in non-poor households, it was found that women are the household's head in only 9% of them and only in 19% of the households the children are not attending schools. With respect to income, most of the poor households (94%) do not receive income derived from non-agricultural activities. In fact, only 1% of them have their own business, 1% receives money from family relatives that have emigrated to other countries, 1% has a stable employment and 2% receives income by trade (Chapalbay et al. 2007).

In Jequetepeque, the poor households are settled on lands with poor quality soils and steep slopes. Despite these unfavorable conditions, during the last decade these lands have been cultivated without interruption by fallow periods. Unlike Ambato, 50% of the poor households are located at the end reach of the irrigation channel. The area of their farms is also different among the watershed households. More than 50% of the poor ones have less than 0.5 ha while only 7% of the non-poor households have such small areas. The poor households (87%) can not contract labor whilst 63% of the non-poor households can. Like Ambato, the women are the head of the families in many poor households (31%) while rarely in the non-poor families (5%) (Gomez et al. 2007).

3. Humid watersheds nearby big cities (Fuquene watershed, Colombia)

In this watershed the differences between poor and non-poor households are enormous. The proximity to the Bogota city (capital of Colombia) contributes to this asymmetry by distorting the traditional profile of Andean watersheds. This leads to increments in the land price that may exceed the US$25.000 ha^{-1} and the wealthiest families can own extensive and very productive areas (100 ha aprox) dedicated to dairy production in the lowlands of the watershed, surrounding the Fuquene Lake. These livestock systems can reach annual milk productivities of 10000 lt ha^{-1} and 30 t of forage (dry matter). In the upper parts there are also wealthy farmers dedicated to the intensive production of potato located in very high OM soils, where productivities can reach 40 t ha^{-1}. In contrast, the poor households are mostly located in the middle parts of the watershed, where soils are less deep and slopes are steeper and prone to degradation. Cereals are cultivated in rotation with pastures and potato . Productivities are not as high as those in the upper parts of the watershed. The poorest households are characterized by not owning land, by having women as the head of the family and by being employed in operations of dairy farms. However the incorporation of milking machines has displaced these laborers, leaving especially women without employment.

4. Humid watersheds located away from big cities and in lower altitudinal ranges (Altomayo watershed, Ecuador)

Poverty profiles of five microwatersheds of the Altomayo watershed were determined. These microwatersheds supply water to downstream urban towns. It was found that 20% of the total households live under conditions of extreme poverty and about 17% are considered non-poor. Also there are differences across the microwatersheds regarding the proportion of extremely poor households (between 8 and 32%). The non-poor household's proportion is in the 12-24% range among the microwatersheds. This variation is attributable to the high migration process happening in the region, where many families colonized lands in the upper parts of the watersheds, particularly families without economic resources. Detailed information is found in Moreno & Renner (2007).

Discussion and lessons learned

The activities of this project aimed to determine if environmental services can be used as a entry point of rural development strategies. This implies a different approach compared to the one adopted in the design of PES schemes with conservation objectives only. Our objective required to analyze if it would be socially efficient to make an investment to provide better ES and how the poor might benefit from it. This demanded an approach that, although it still needs to be improved, has provided the basis to discuss methodological, conceptual and operational aspects of the process to design a PES scheme. These main aspects are:

Conceptual aspects

- Targeting spatially the economic compensations in order to maximize the provision of the service, the overall socioeconomic benefits and the profitability of the investment

The environmental service can be used as a driver of rural development if it is well defined, its socioeconomic implications are studied and there is willingness of providers and beneficiaries to cooperate towards the conservation and provision of these services. However, this requires knowledge about the magnitude of the provided service and its associated co-benefits (socioeconomic benefits). The most common water-related services in the Andes are related with streamflow regulation and sediment yields. However not all interventions in any place of a watershed will result in the same level of impact on the service and even more will not necessarily contribute to maximize social benefits and profitability of the investment. This will highly depend on the marginal productivity caused by the modification of the land use and the service and on the opportunity cost to implement the required land use changes. In this sense the project has provided a methodology to define those service providing units (e.g. HRUs) as the unit at which the trade offs with the resultant socioeconomic benefits can be assessed. Although the definition of these units relied on the use of hydrological models developed under different conditions (SWAT was developed in USA), they still provide insights into the priority areas in a watershed and have permitted to quantify the tendencies of the impacts on hydrological services under different land use scenarios. The model performance can still be improved through more field research for adjusting and validating the model but the approach can be considered as valid . From the socioeconomic perspective, the project developed a linear programming model (ie. ECOSAUT) that permitted to combine SWAT results with socioeconomic data to study the trade offs between the environmental and the socioeconomic benefits. The model is an open access tool for which the validity of the results depends more on the quality and reliability of input data than on the model itself. Also, the project has demonstrated the importance of advancing towards targeting of compensations in the watershed since spatial location is an essential factor when including social and economic efficiency aspects of the investment .

- Pro-poor PES schemes demanded complex economic methods to understand how the distribution of benefits can reach poor sectors.

Ravnborg et al. (2007) found that in 65% of identified PES case studies, hydrological services are being involved. At the same time, the project through its poverty profiles analysis found that the poorest households do not own land (Gomez et al. 2007, Chapalbay et al. 2007). Traditional analysis focused on valuing the benefits for direct service providers and beneficiaries is limited because it does not permit to assess the real impact of PES schemes on those poorest households that may be benefited indirectly by the multiplier effects of proposed land uses likely to provide ES.

- PES is not always the best economic mechanism to provide incentives for land use alternatives that deliver environmental services

The purpose of the economic analysis in many of the study sites was to determine the opportunity cost of implementing different land use alternatives prompted to deliver better watershed services. The rationale behind this was that for a farmer to change from conventional uses to alternative ones, he must bear an opportunity cost (Antle et al., 2007). In the Fuquene case, this cost was the difference between the conventional and the conservation tillage returns. Therefore, only conservation tillage systems capable of producing equivalent or greater yields and returns than conventional tillage are likely to be readily accepted by the producer (Muller et al., 1981). The results of our studies showed that in some cases there are alternatives with negative opportunity costs and as such a payment or compensation of watershed services needs to be reconsidered. This was the case in Fuquene. Conservation tillage increases net return implying a negative opportunity cost and therefore a net economic benefit for the farmer. Our results compared well to the current rental price of a hectare of land in the study area (US$1870 vs. $1200, for the simulated conventional tillage system vs, the actual rental price of land, respectively) if we take into account that net revenue should not only be a retribution to land price but also to the administrative costs, being this last the difference between the two values. This explains the fact that currently land is cultivated by its owners instead of being rented as they can get greater returns cultivating by themselves and using their own labor in most of the activities. Also, we suggest that the willingness of owner to rent their land will be less as net revenues increase with the conservation tillage system. Better mean net returns from conservation tillage are also reported by Sandretto (2001) and Jeong and Forster (2003) who attributed this to decreases in input costs particularly due to reduced labor hours due to a decrease in the number of trips to crop fields, reduced machinery wear, and a saving in fuel consumption. In our case reduction of input costs are only related to reduced machinery operations and fertilizers applications.

Thus the results of this study indicate that conservation tillage is a "win-win" alternative for Fuquene farmers by benefiting economically the farmer and by contributing positively to the watershed service as evidenced with indirect data analysis of soil characteristics that influence water movement in the watershed. In other words there is a complementary tradeoff between the economic and environmental benefits. However, Uri et al. (1999) recognized that conservation tillage on highly erodible land will unquestionably result in an increase in social benefits, whilst the expected gains will be modest. Similarly a 17% of increase in net revenues in our study area would be not enough to overcome the possible aversion to risk (or other adoption barriers) of farmers and encourage them to make an additional investment to cover initial extra costs of conservation agriculture (ie. cultivation of oat as cover crop). This fact may explain why this practice is not widely adopted in the Fuquene watershed (Currently there are about 1800 ha implementing these practices of 16933 ha under potato production in the watershed, (Otero, pers. comm.2009; Quintero and Otero, 2006)). This same situation has been described by Sandretto (2001) who showed that although mean net returns on reduced tillage practices are equal to or greater than the returns from conventional tillage, mainly because of decreases in input costs, yet conservation tillage practices have been adopted on only 35% of US agricultural lands. The factors that have been reported as barriers to adoption of conservation agriculture practices are various. First, the additional risks perceived by farmers when adopting reduced tillage including the human and/or physical capital investments that producers may have to incur (De la Torre et al., 2004). The availability of credit to assist with the increased need for purchased inputs (such green manure cover crop seeds, herbicides, etc) for conservation tillage is another factor. In fact, successful experiences of conservation agriculture practices adoption in Latin America have demonstrated the importance of credit as an important enabling factor (FAO, 2001). On the other hand, according to Tweeten (1995), for farmers with short-term planning horizons the benefits of conservation agriculture are not immediate. This becomes an additional barrier for adoption. Also, there may be other barriers particular to culture and recent history (Nyagumbo, 1997),

and to information aspects such as contact with extension agents, availability of technical assistance, attendance to field demonstrations and plots, etc. (FAO, 2001).
Therefore, our results show that although conservation tillage practices are feasible in mountainous areas and low income countries such as our study area, existing barriers may constrain wide adoption of these practices. One factor important for enhancing the adoption may be the required investment and therefore credits or other financial or economic incentives different to PES (Carcamo et al., 1994). In fact, this has been demonstrated in the study area were a small revolving fund was created to provide credits to farmers willing to implement conservation tillage in their potato-based production systems. The credits were created only to cover the required investment to implement the cover crop as the potato production costs are assumed to be covered by the farmers as they are used to do. This system, although small, has proven to be effective since 2005 incorporating about 180 small farmers every year and using the capital of the fund at its maximum capacity (Quintero and Otero, 2006; Rubiano et al., 2006). (See Objective 2 section).

- Trade off between macroeconomic policies, employment generation and competitiveness

There is a lack of coherence between the macroeconomic policies and the desire to increase employment opportunities in the Andean countries. Many subsidies given to the rural sector for modernizing the production systems have resulted in an increased use of machineries displacing the labor use as has been the case in the dairy production systems of the Fuquene lake. These kinds of macroeconomic policies deteriorate the competitiveness of the rural sector by increasing the use of tradable goods instead of keeping using domestic resources. Then, the analysis of the effects of changing land use should incorporate the analysis of competitiveness because this may affect directly the poor beyond the mere impact of changing the provision of an ecosystem service. This is especially important when the objective is to use these services as an entry point to improve a more equitable share of benefits in a watershed (i.e. by means of payment for environmental services).

The validity of SWAT results and its appropriateness in the Andes

It is very common that hydrological models are calibrated using sensitivity analysis which identifies the variables that influence most on the resultant output values (i.e. water and sediment yield). In general these variables are modified in a ±10% range until the simulated results match well with measured values. However when there are big differences between measured and simulated values in certain critical points this might be not the best procedure to adjust the model. In this sense the best practice is to understand which characteristics of the data and of the watershed may be causing these big differences that can not be adjusted with conventional sensitivity analysis. This will not only enable the model user to obtain a better simulation but to improve his understanding of the watershed. This situation is very likely to occur in the Andes watersheds.

Particularly, the efficiency of SWAT simulations in the Andes will depend highly on the watershed area. For example, in watersheds bigger than 10.000 hectares SWAT efficiency will likely be good as more climatic stations may be located in such a big area –representing better the spatial variation of rainfall, and the response time -the amount of time it takes for rainfall to reach a stream, is higher than 10 hours which in fact means that one daily streamflow measurement will be a good approximation of real streamflow occurring on that day. However, when modeling smaller watersheds, calibrating the model might be not straightforward, not because of the model itself but because of the Andean watersheds characteristics and the nature of streamflow and sediment measurements. The moderate and steep slopes characteristic to the Andes and the high intensity of the peak rainfall events shorten the response time to even less than 4 hours and thus peak streamflows are not reflected in a unique daily streamflow measurement (generally measured every 24 hours). This results in big differences between the reported daily streamflow and the actual maximum stream flow for that day. Under this situation it is very likely that simulated daily streamflow results in higher values than the measured value. It is very common that instruments used for measuring streamflow are not able to register adequately these few but common peak values in the Andean watersheds.

This might be explaining the difference obtained in some cases. For example for the Mishkiyacu watershed (Peru), there were differences between the magnitude of the simulated and measured streamflows during peak rainfall events (although the model simulates well the moment those extreme events occurred) (Quintero et al. 2009).

With respect to intermediate streamflows which are related to rainfall ranging between 60-80 mm and well distributed throughout the month the simulated streamflows matched better with the measured values than what occurred with peak streamflows. This may be related with the fact that there are no major variations between hourly streamflows so one daily measurement represents well the actual daily streamflow. Similarly, the minimum streamflow simulations were even better adjusted to the measured ones (intermediate and minimum streamflow represent 96% of the data used for many of the models calibrations in the studied watersheds).

Further improvements in intermediate stream flows simulations can still be done with more spatially detailed data about the varieties of crops, the fertilization levels and the crop management (SWAT is able to model biomass growth according to detailed crop information). These aspects influence photosynthesis and therefore the evapotranspiration which is the hydrological variable that affects importantly the water balance under conditions of high soil water infiltration rates due to the high amount of soil organic matter (e.g. Mishkiyacu watershed). Thus, any variation in intermediate streamflows is more dependent on evapotranspiration.

Thus, a good adjustment of the model depends on the understanding of hydrological processes, the characteristics of the watershed and the type of measured data used for calibrating the model. This kind of approach is necessary in the Andes where the frequency and means to measure hydrological data is limited and the watersheds have short response times during extreme rainfall events. Being said this, and taking into account that in most of the cases the trend of simulated series fit well with measured values, we believe that despite data limitations in the Andes, the SWAT model still permits to identify those HRU with higher incidence in water and sediment yields and to give an approximation of the magnitudes.

Pros and cons of our methodological approach

The SWAT model has generally a good potential to develop time and cost-efficient analyses for watershed management and decision-making (Jayakrishnan et al. 2005). The main benefits of the SWAT approach are that a) watersheds where no monitoring data are available (e.g. stream gage data) can still be modeled and b) the relative impact of alternative input data (e.g. changes in management practices, climate, vegetation, etc.) on water quality or other variables of interest can be quantified (Neitsch et al. 1999).

SWAT is universally applicable, because its physical equations can be used for any climatic zone or land-use type (Heulvelmans et al. 2005). Some SWAT empirical equations (e.g. curve number technique and Modified Universal Soil Loss Equation -MUSLE) were developed from field experiments in the USA, and should be varied accordingly when employed elsewhere. In fact, during model calibration for Andean simulations the runoff curve number and MUSLE factors had to be modified to obtain realistic output values, as precisely recommended by SWAT developers during calibration. However, SWAT is able to manage the heterogeneity of biophysical conditions typical in the Andes (soils, topography, land uses and weather). Yet, detailed input data such as streamflow measurements (see discussion above), rainfall and soil data will definitely improve SWAT's simulation in Andean contexts. Analogous observations have been made for SWAT applications in Africa (e.g. Jayakrishnan et al. 2005).

However, SWAT is still very useful for prioritizing HRUs as the simulated series of streamflows compare well to the observed ones. Thus, the model permits to safely identify critical target areas for service provision, although the absolute quantitative predictions of 'services rendered' may still be improved. More detailed soil data will help to increase resolution when defining HRUs. In the Andes it is relatively easy to find good resolution of land use data but soil data are still too general for small watersheds (1:100000). Thus, the efficiency of hydrological simulations in the Andes still needs to be improved by generating better input data, especially streamflow, daily rainfall and soil parameters, but this does not deprive us from the capacity to identify and prioritize the service providing units (HRUs).

For the economic analysis, optimization models depend on quality data about benefits and costs of production systems, which is relatively easy to collect. However, data about default deforestation and other land-use change rates (incl. their fluctuations over time) used for scenarios analysis could critically affect incomes. Hence, this information in many cases needs to be refined.

Nevertheless, we believe this methodological approach can still orientate systematic efforts to prioritize actions in cases like the Andean watersheds, where a complex environmental reality -in terms of multiple land uses, slopes and soil types, has to be assessed. Eventually, this should also stimulate researchers to propose adjustments in innovative benefit sharing mechanisms such as PES, including spatial targeting of high-service provision areas. Supplementary factors could be added, such as the special contribution of cloud forest to flows that was not considered in the hydrological modeling in our studied watersheds.

In addition to the lack of data in many Andean settings, complex cases can also trigger high transaction costs -for those interested in designing PES schemes, in integrating biophysical, social and economical information at different scales. The methodological approach employed for quantifying and assessing the impacts of land use changes (combining SWAT and ECOSAUT) simplified the process of integrating this knowledge by homogenizing the scale of analysis (HRUs), determining the minimal information needed and including socioeconomic and environmental variables in a single tool for land uses economic assessment.

Finally, whether this kind of analysis is required for implementing PES schemes (e.g. quantification of environmental services, estimation of opportunity costs and identification of service providing units) depends on the settings and context of the area. For example, there are already PES schemes in the Andes that have operated for almost a decade without previous studies. One example is the Pimampiro PES scheme in Ecuador where the lack of ex-ante studies may be explained by the low level of investment made by the municipality and conservation organizations–accumulated start-up and running costs combined for 2000-05 were US$62,987 (Wunder and Albán 2008: 689). Also, the few number of land holders, the small land area located in the watershed supplying water, and the forest conservation purpose of the scheme make it relatively easy to allocate these funds. In such cases conducting detailed studies and incurring high data collection costs may not be efficient investments. Following this rationale, these studies may be necessary if the investment is conditioned to a previous demonstration of the importance of conserving forests or implemented land use changes for providing the watershed services. However, when potential payment amounts are higher and the alternatives more complex, as is the case of some of our study sites (e.g. Moyobamba, Peru), the need for hydrological and socioeconomic *ex-ante* analysis (quantifying watershed services, identifying service providing units and estimating opportunity costs) to target the investments is essential (Quintero et al. 2009).

Challenges for applying hydrological modeling for the design of PES schemes in the Andes

The main challenge for improving the performance of hydrological modeling in the Andes as a means to simulate the behavior of hydrological services such as sediment retention and water flows regulation is to improve input data related with climatic information, grasses-cover and soil characteristics. Climatic stations in many watersheds are not enough in number to cover the spatial variation of precipitation. It is common to find stations in the 1000-2800 m altitude range but few in the upper parts (above the 3000 m altitude) and in the piedmonts where the precipitation is importantly different. Thus, performance indexes of modeling exercises are low when simulated stream flows values are distant from the measured values.

However, the increment of available data does not only need a financial effort but requires a substantial period of time to permit the gathering of data series long enough to simulate adequately the hydrological behavior of a watershed (ie. 10-20 years). To ameliorate this difficulty in the shorter-term –while the coverage of the climatic station network is expanded, the models to simulate climatic data may become an alternative. The CPWF Andean Coordination supported the development of an Andean version of MarkSim, a climatic model that was very useful to obtain information of watersheds for which there was not appropriate climatic data for hydrological modeling. Future efforts should be focused on continued validation of this model and adjusting it as new climatic data become accessible in the Andes.

With respect to soil data, it is important to know the values of soil characteristics that influence the hydrology in a watershed such as organic matter content, bulk density, available water content, and percentage of silt, sand and clay. However, for many Andean watersheds, the available soil surveys do not include the values for all these characteristics and most of them only describe the texture of the soil map units. In these cases, the other characteristics are indirectly determined using the Soil Characteristic Tool (Saxton et al. 1986) based on the texture data. However this tool was developed for mineral soils and as such is not applicable for high organic matter soils as those found in the high Andes (e.g. Paramo soils may have up to 30% of organic matter content). This high organic matter content confers to these soils unique properties that favor the soil water retention which is crucial for maintaining stream flow throughout the year. Under this context, the project had to conduct field sampling to measure directly these characteristics. However it will be desirable that future efforts in the Andean countries will be oriented to updating and completing soil surveys especially for these characteristics.

With respect to land covers, the project has found that it is crucial for hydrological modeling to differentiate between the various types of pastures as its growth characteristics may influence the infiltration of water into the soil profile. In general, default values in the model do not distinguish between the different pastures that may occur in a watershed. In temperate countries, where most of the models were developed, annual grasses reproduced by seeds are found, which are grazed only during spring and summer seasons. However in the Andes the conditions are contrasting as perennial grasses with different growth characteristics are found. Above the 2000 m altitude, native and introduced grasses (e.g. *Penisetum clandestinum*) commonly spread by stolon and as such favor the water infiltration reducing the surface runoff. On the contrary, at lower altitudes the grasses are reproduced by seeds (e.g. *P. maximun, H. ruffa, B.decumbens, M. minutiflora*) and their coverage is not uniform throughout the soil surface leaving spaces between the plants. This cover is generally lost after the senescence leaving the soil unprotected at the beginning of the rainfall season. Being the pastures one of the most important land cover in the Andes, future efforts may be oriented to determine curve number (a parameter used for modeling surface runoff) for the different phenological stages of the pastures under different management regimes.

2 Objective 2. Generate appropriate information and institutional platforms to create strategic alliances needed to implement PES pilot schemes and new land uses or management practices likely to deliver watershed services.

Having the Andean Watersheds Project (AWP) of the GTZ as main development partner in the project it was possible to create strategic alliances required to implement pilot economic and financial schemes oriented to stimulate land use alternatives that may contribute to modify positively environmental externalities. Moreno & Renner (2007) recognized that the improvement of the knowledge on the hydrological dynamics of the studied watersheds and ex-ante analyses of opportunity costs and benefits derived from proposed land use changes were essential for discussing with local stakeholders different economic and financial schemes. Apart from these analyses, already explained in objective 1, the project applied other methods to explore the willingness to cooperate of service providers and beneficiaries. This facilitated the understanding of the rationale behind the stakeholders before the discussion of a specific scheme.

Methods

Knowing that information generated in objective 1 per se is not enough to promote changes, the project, in collaboration with the Javeriana University-Bogotá campus, included economic games as part of the methodology. The information resulting from the objective 1 was used to design decision-making games through experimental economic techniques to determine stakeholders' willingness to collaborate and negotiate. Thus it was possible to observe, in a more controlled environment, how incentives and institutions were governing the individual decisions affecting outcomes at individual and group levels (Cardenas 2003). The decision-making games were played by individuals from local communities in the upper and lower parts of the watershed who have the choice to change their current land-use scenarios or/and make a payment to provide an incentive for these land-use changes. These decisions were studied under different scenarios: a scenario of negotiation where the different players were allowed to discuss before taking a decision; a scenario without communication which may correspond to the baseline; and a scenario were certain decisions are enforced by the application of penalties to players that do not incorporate better management practices or do not pay to the service providers (Cardenas and Ramos 2006). The economic games results permitted to analyze the possibilities and limitations of actors to resolve cooperation-related problematics and to establish to what extend reciprocity, trust, inequity and risk aversion influence the decision making to resolve common goods dilemmas (as those related to the provision of watershed services). Detailed information about games design and application are described in Cardenas and Ramos (2006).

Results and Discussion

The use of experimental economic games has demonstrated that individual decisions on natural resource use do not obey classical economic theories, which state that rational people maximize their profits without taking into account the well-being of others and have a self-interested behavior when opportunities appear. Preliminary exercises with experimental economics make it possible to identify the willingness of the stakeholders involved to cooperate in an environmental conflict. Many facets of the problem have to be considered, especially those related to power relationships and conflict of interests. This is where collective action plays a role in promoting understanding among the parts, reducing negative externalities and improving the benefits of all parties. These games, based on conflict understanding (interdependencies among parties) and having stakeholder representatives as participants, identify the willingness to cooperate in solving the environmental dilemmas. The games consisted of simulated exercises where different actors in a watershed such as farmers, cattle ranchers and urban dwellers modify their decisions to negotiate the current environmental conflict in consecutive rounds. Providing players with different decision options simulates the decision-making process, where the participants must choose between implementing changes in the current land-use scenario and rules, or maintaining current practices, uses and institutions.

The context and issues of the watershed were mirrored during the process. Land use/management changes were discussed in the light of changes in income or environmental impacts. Some changes in land use mean reduced income for some stakeholders; thus social and biophysical interactions abound during the simulated discussions. Payment schemes and negotiations among both upstream and downstream stakeholders were suggested; and cost figures or values inherent to those changes were also introduced in the game. As a result of these games, the individual rationality that oriented the decision-making process was revealed.

Especially for the Fuquene watershed, the economic games were very useful and illustrative of the complexity of interests resulting from a high socioeconomic asymmetry occurring among the actors settled in this site. In this case, cattle ranchers located in the lower zone of the watershed had the major assets and lowest discount taxes in relation to water resources. They are not open to investing in regulatory organization, much less to exploring ways to reduce their detrimental management practices. For the games, three main questions were answered: 1) Which stakeholders will continue with the same land management practices?; 2) Which ones are willing to change their management practices?; 3) Which are willing to pay or compensate to those making beneficial changes in their systems?

All these questions involve dilemmas among individual and collective decisions, between the farm or plot scale and the aggregated effect at subregional or regional scales. The answers found to these questions in the Fúquene case are shown in figures 18 and 19. Figure 17 refers to the mean of individual decisions of potato growers adopting conservation farming practices. Figure 18 corresponds to the mean of individual decisions of water consumers accepting to transfer funds to potato growers in order to promote the proposed technological change. Both decision-making simulations were conducted under four scenarios:

- Allowing communication between farmers and downstream, water consumers before individual decisions were taken
- Without communication (current scenario)

- Applying low sanctions
- Applying higher sanctions

Results demonstrated an important potential of collective action to achieve technological changes by means of incorporating payment for environmental services schemes. However it highly depends on the possibility of negotiating among those actors and on their awareness of the relationship between land use and hydrological externalities.

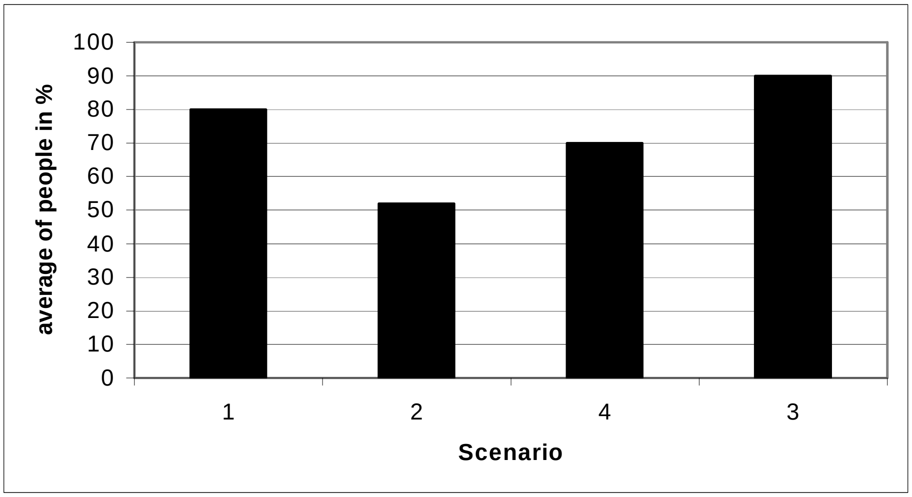

Figure 18. Individual decisions made by potato growers adopting conservation farming practices. (*Source*: Maya et al. 2004).

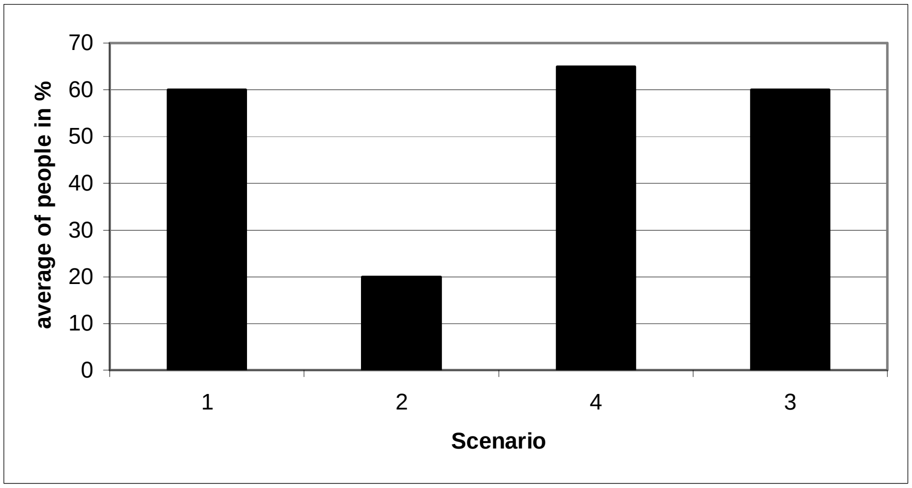

Figure 19. Individual decisions made by water consumers accepting to transfers funds to promote conservation farming in potato production systems. *(Source*: **Maya et al. 2004).**

Experimental economics made its biggest contribution by revealing the interdependencies of the problem among the stakeholders. In this case study, this consisted basically of showing how different crop- and soil- management practices affect water quantity and quality. When the participants understood that quantity and quality of water flows are externalities, they realized that local agreements with their neighbors are a self-control mechanism for implementing the appropriate land uses. At the same time, the economic game revealed a preference of local communities to accept local rather than government organizations managing resources because of the poor reputation of the latter. The project still believes that once stakeholders understand the causality and relationships among those generating the externality and those being affected; the emergent collective action will motivate the required changes. However all the results of the economic games inspired the team to design a financial scheme to share the costs of implementing the desired land management practices, as will be explained below.

Financial and economic schemes to provide watershed services

The project achieved the creation of two schemes in two of the five studied watersheds: Fuquene and Altomayo, which will be described below. In the other three watersheds the project contributed with information and institutional processes that are currently the basis for the negotiation of similar schemes. In Jequetepeque the generated information along with the creation of a watershed coordination committee are currently the basis for designing and negotiating an eventual PES scheme. This effort is now being lead by a PES project carried out by WWF (World Wildlife Fund), CARE and IIED for which our project team conducted the studies described in objective 1. In Ambato, the study results are currently considered in the negotiation of a benefit sharing scheme to be applied by the Tungurahua Provincial Government with the aim to recuperate the costs of the construction of two reservoirs according to the different benefits that will be derived from this to farmers, city water users, etc. In the Tunari Mountains, the project outputs served to understand the hydrological dynamic of the watershed and the constraints to improve the watershed services with mere economic payments. In Westermann (2008) are given the main considerations and recommendations for future efforts oriented to design a PES scheme. The main aspects are:

- Hybrid schemes: Conservation and development initiatives: PES is only one of multiple strategies to promote the conservation and improvement of watershed services. It is suggested to consider PES jointly with conservation and development projects in order to maximize investment from multiple sources and to reach poor sectors that not necessarily may be prioritized in a PES design (of which the main objective is to target the environmental externality)

- Individual vs. collective providers: An eventual payment should not necessarily be targeted to individual farmers (service providers) rather than to groups or communities. It is common to think that payments should be traded between one single buyer and one provider. However taking into account the very small areas owned by farmers it may be the case that several farmers are required to change their management practices to improve the watershed service. Thus, aggregating them may contribute to reduce transaction costs and ensure that the required area to achieve the desired impact on the service is attended.

- PES for conserving vs. PES for improving land use: A potential PES scheme could be oriented to protect remaining natural land covers by restricting its land use conversion (as most of the existing PES schemes in the Andes) or to stimulate land use changes and better technologies that can improve the watershed service. If the purpose is to favor the poorest as well, the second option may imply more opportunities for those without land and whose income relies on employment opportunities in production systems of others. At the same time the promotion of better management practices instead of restricting the use of lands will be more feasible if it is considered that more than 53% of the poor people own less than 0.25 ha. In this way they will not be able to sacrifice land and leave it for natural regeneration. Instead they may need better management practices that not only improve the level of provision of watershed services but improve the productivity of their parcels.

- Payments: in-kind vs. monetary payments; perpetual vs. transitory payments: The PES scheme design can consider non-monetary payments such us the construction of infrastructure (schools, health centers, etc) and training on promising activities to improve income in rural communities. These kinds of payments have the advantage of staying in the communities in the long term, especially when the payments are used for the building of capacities. However the disadvantage is that not all members of a community take advantage of these new capacities and as such would not perceive this as an incentive or payment to deliver a service. Also it was found that incentives such as employment generation for those without land and the provision of materials for implementing land management can be highly valuated by the farmers even more than monetary payments. The monetary payments are easily used for anyone and can be rapidly reflected in the coverage of immediate necessities. However, at the same time a PES scheme can not guarantee that the payment is oriented to cover the priorities of poor households. On the other hand, the fact of giving payment for an ecosystem service has in many Andean communities a negative connotation by being related wrongly with the privatization and appropriation of natural resources. In addition to this, it is still unknown what can be the effect of providing a big initial payment to cover a large investment (e.g. the construction of infrastructure) that can be oriented to pro-poor objectives as well vs. small perpetual payments that can be on a contractual basis conditioned to the provision of the service but not necessarily can attend immediate needs of poor households in a watershed.

Westermann (2008) also highlighted the pros and cons for designing PES schemes in the Tunari microwatersheds. The pros are related with the land tenure security as all private and communal lands are legally recognized, reducing the risks of invasion and favoring the contracting processes with service providers. The second positive factor is related with the favorable social organization that is completely inclusive and as such incorporates all farmers regardless of their socioeconomic status. This can favor the design of PES schemes oriented to trade a service between organized groups rather than between individuals, and therefore reducing the transaction costs (although this option demands an efficient social control to monitor the compliance with obligations). Existing power relations inside the social organizations are possible limiting factors that could cause the misuse of the payments by being invested in activities that do not necessarily incentivize the provision of the service. Another limiting factor is the socioeconomic and cultural asymmetry between the upstream farmers (service providers) and the downstream farmers (service beneficiaries). This can limit the negotiation capacity of poor farmers (upstream farmers) even though their organizational capacity is recognized as strong. Thus a PES scheme in the Tunari region should be focused on developing bridging social capital (rather than bonding social capital) in order to close the gap between providers and buyers and therefore, to endeavor a fair negotiation. For this, all information about opportunity costs and willingness to pay analysis has to be disseminated and explained to service providers.

Altomayo watershed

The project facilitated the creation of an intersectorial committee for the promotion of a fund to pay for ecosystem services. The Municipality and the water supply and sanitation company (EPS -a public entity but operating under private law) were part of this PES committee. This process was accompanied by a permanent politic dialogue that aimed to contextualize and disseminate the implications of putting in place a PES scheme. At the project finalization the fund was created. The idea was to levy a surcharge on Moyabamba's water consumers, and correspondingly subsidize upstream farmers willing to change towards less sediment-prone land uses (Aspajo 2006). The water surcharge was approved by the corresponding national authorities and the water users, and currently the payments are being collected and deposited in a specific bank account. Nowadays, it is under discussion if the payments should be used either as recurrent payments or subsidized conditional credits. The challenge will be to bring into practice the prioritization of HRUs and of land use alternatives made in objective 1 for the micro-watersheds, as a means to optimize the use of these resources. The results of this analysis concluded that changing the land use in prioritized HRUs could potentially cut sediments by 18% while improving the income and therefore, subsidized loans for shade–coffee adoption could be even better and cheaper than a permanent PES scheme. Paying upstream farmers to abandon or set aside cropped areas in favor of forest regrowth would have been an economically and politically less feasible solution. On the one hand, high immigration and lack of land titles undermine the potential use of PES to avoid new deforestation. On the other hand, watershed services there need not only protection, but also active restoration through reconversion of intervened areas to more benign land uses. In consequence, win-win alternatives like shade-coffee that require an initial PES-like conditional incentive for adoption, but then allegedly can be self-sustained, have functioned elsewhere (e.g. Pagiola et al. 2004), and could thus be more attractive than perpetual compensations (e.g. for live barriers), as long as the former can be sustainably adopted in practice (Quintero et al. 2009). Aspajo (2006) describes in detail the participatory and political process undertaken for the creation of this PES scheme.

Fuquene watershed

Results from analysis conducted under activities of objective 1 indicated that a switch to Conservation Farming practices (i.e., reduced tillage, permanent cover and green manure use) would have the most beneficial impacts overall, and especially on controlling erosion and nitrate and phosphate leakage into the lake. Based on these results the project sought to reduce eutrophication in Lake Fuquene by encouraging upstream potato farmers to use less fertilizer and more environmentally friendly cultivation techniques. Thus, conservation agriculture was promoted as one of the primary means of accomplishing these goals and reducing the amount of organic nutrients (nitrates and phosphates from fertilizer and animal wastes) in runoff water to the lake. In order to facilitate land management changes, GTZ and Ford Foundation helped significantly with start-up costs to create a revolving fund for providing soft loans (0.9% interest rate) to the smallest and poorest farmers (<2ha). These loans are specifically targeted to small farmers via their farmer associations. This credit subsidy was conditional upon the farmer presenting an approved land-use plan, accompanied later by technical follow-up assistance from a GTZ and CAR technician. Compliance with the land-use plan was around 97%, and over time the scheme doubled its initial cultivation area reaching 178 hectares per year. In this sense, the project clearly was a success; the mechanism worked as planned, and seems to be sustainable. The project was so far less successful in scaling up the initiative within the entire watershed, which is sized 99,137 ha, 55,662 ha of which are under cultivation. Transferring the idea to the commercial banking sector was so far not successful. Some producers remain skeptical about changing cropping practices with a century-long history. Some particularly larger landowners are leasing out their lands to commercial producers of in particular potatoes. When the functions of landowner and farmer are divorced, the latter has little incentive to preserve soil fertility for the future, or to make investments in the land that give returns beyond the short-run lease period. The tenure arrangements are thus one significant obstacle for upscaling. Key to this small scheme success was the cooperation with and involvement of local government through the environmental authority (CAR) who is in charge of the technical assistance and the participation of research institutions (CIAT) that provide reliable information about the environmental and economic benefits of conservation agriculture. Currently the revolving fund is under operation covering about 180 ha annually and the capital is being recovered every year. Quintero and Otero (2006) describe in detail the participatory and political process undertaken for the creation of this financial scheme.

Thus, this scheme in Fuquene, through its established rules, has tried to reach the smallest and poorest farmers by including the farm area as criterion to provide the loan. In this way this scheme is not only aiming to stimulate changes in the conventional management practices of potato cropping but is targeting the economic incentives to those that have major problems to cover the extra investment for incorporating the green manures into their rotations. The main constraint to the smallest farmers is their inaccessibility to commercial banks credits to overcome their limited cash flow, which keeps them away from new and profitable land management alternatives that demand initial investment.

Further efforts should be focused on how to enlarge this fund to reach a wide adoption of these practices whether by incrementing the capacity of the fund or by providing an extra incentive. The latter may come via payments for other environmental services such as net Greenhouse Gas removals. Quintero (2009) found that in 7 years of practicing conservation tillage in the upper Fuquene watershed, 788 t CO2 ha^{-1} are sequestered which could mean an extra income of US$450 yr^{-1} (assuming a carbon price of $4 per t CO2 which is a conservative price. A constant carbon price is assumed as currently carbon contracts are negotiated on a constant price basis). This carbon payment alone could cover oat production costs that are around $377 ha^{-1} and increase the net revenues over the remaining years of the rotation when oat is not cultivated (in a 7yr period oat is cultivated twice), This may mean to the farmer a 29% increase in net return instead of 17% derived from the economic benefits of conservation tillage alone.

Although this estimation is based on a conservative carbon price of US$4 per t CO2, this price already covers the cost of sequestering 1 t CO2 in the 7yr-period. If we consider that this cost may be equal to the additional investment the farmer had to incur, which is the oat production cost (US$377 x 2), then each ton of CO2 requires an additional investment of US$1. Of course, this calculation does not include the costs of technical assistance that is currently provided by the regional environmental authority (CAR).

Thus, it is recognized that off-site benefits of conservation tillage are not only related to watershed services and therefore financial incentives should be designed on this basis. Carbon sequestration by conservation tillage can imply various other co-benefits for society such as soil retention and therefore the reduction of downstream sedimentation and regulation of rivers flows (FAO, 2001). Thus, showing all conservation tillage benefits for society together may be a strong strategy to design robust and stable financial incentives for enhancing adoption of conservation agriculture in the Andes.

Conclusions and lessons learned

Experimental economics through economic games constituted a promising methodological approach to study the willingness to cooperate in the watersheds. However, its application was quite limited in watersheds with high socioeconomic asymmetries, like the Fuquene watershed. The downstream wealthiest farmers did not attend the economic games and even did not want to participate indirectly through phone calls. This apathy to participate with smaller farmers in activities to discuss the water problematic of the watershed can be related with their own interests. They own the most expensive lands that currently have a good volume of water allocation and may not be interested in incurring new payments. On the contrary, the downstream small farmers participated in the economic games and showed their willingness to compensate upstream farmers for incorporating management practices that can result in the reduction of soil and nutrient loss. This willingness to cooperate was shown to be dependant on good communication between the parties, otherwise the compensation was not given (in the economic game context). Thus economic games were useful to understand the conditions under which the compensation may be feasible. However still some issues remained unanswered with this methodology, for example how the willingness to pay can vary with different amounts of payments (using real magnitudes in the game rather than symbolic numbers as used in the exercises) and to what extend and under what conditions the wealthiest farmers may participate in such payment schemes.

Another lesson learned is that to start up the whole process in HRUs such as those of Altomayo and Fuquene, an investment is required to facilitate dialogue and communication, the implementation of participatory methodologies to include all stakeholders, ex-ante analysis to know the magnitude of the service and the opportunity costs for implementing desired land uses, etc. Investment in this project, as in other PES schemes in Latin America, was covered by the donors (CPWF and GTZ) and was not charged to the created schemes. Although in theory it may be desirable that all those transaction costs should be included in the costs of the scheme, this may reduce its viability and for that reason costs are commonly assumed by external parties (NGOs, governments, etc). This can keep being the situation for other cases of PES-like schemes and should be clearly recognized.

On the other hand, the identification of win-win technological alternatives for improving the environmental and economic performance of conventional agricultural systems is essential. This may contribute to accelerate the process of negotiation by incorporating new incentives for the farmers beyond the mere payments (e.g. improvements on productivity and income). However the implementation of new technologies by small farmers may require PES-like subsidies as was the case in Fuquene, and as such PES-like schemes should be considered, as a complementary strategy in adoption processes of environmentally friendly agricultural practices. Once this role of PES-like schemes is recognized, especially for sites where the re-conversion of land uses and practices is required to impact positively on the ecosystem services (rather than to conserve remaining natural areas), subsequent efforts to incorporate government support in this sort of schemes is required as this may add financial sustainability to the mechanism -if government support is given as part of a policy. This will be more sustainable than relying only on donors support. However the project team found that this still requires strong efforts at the policy levels, as the project team had difficulties to convince the commercial bankers to orient their credits to this kind of initiatives even though the project offered to be the guarantor while the banks had to use the capital allocated by the national government for the agricultural sector (ie. In Colombia). Thus it is necessary to influence at the policy level, especially in the macroeconomic policies context to ensure that agricultural policies reach the poorer rural sector and can be applied with preference to initiatives that result in positive environmental impacts, that in the end result in positive impacts for the whole society (when environmental externalities are addressed). This approach will permit to incorporate the poorer in benefit sharing mechanisms that compromise benefits and costs derived from better water resources management.

To finalize, as the poverty profiles demonstrated, the poorest in the Andes are those without land and therefore pro-poor PES schemes can be difficult to implement. In particular those schemes that pay for conserving natural areas will hardly favor these poorest households. Instead, PES schemes that promote better management practices may improve the conditions of the poorest if the new alternatives provide new sources of employment to landless inhabitants, change the availability of water during dry periods and improve accessibility to good quality water. This demands broader economic and social analysis to be able to link all possible benefits derived from interventions promoted by PES-like schemes to the poor. This should at least include the multiplier effects of modifying income and employment through new land use alternatives, benefits derived from increasing water supply during dry periods and from improving water quality by reducing sediment yields, benefits from better water allocation, and those derived from agricultural productivity changes.

OUTCOMES AND IMPACTS

3 Outcomes and impact proforma

Summary Description of the Project's Main Impact Pathways

Actor or actors who have changed at least partly due to project activities	What is their change in practice? I.e., what are they now doing differently?	What are the changes in knowledge, attitude and skills that helped bring this change about?	What were the project strategies that contributed to the change? What research outputs were involved (if any)?	Please quantify the change(s) as far as possible
CAR (Corporacion Autonoma Regional – In Spanish)	The implemented financial mechanism consisting of a fund for buying conservation farming machinery and for giving soft loans for sowing green manures has facilitated the work of extension agents since they are now using these credits as an incentive to promote the adoption of conservation farming practices.	Knowledge in the actual impacts of conservation agriculture on soil-characteristics that can affect the watershed services and the socioeconomic benefits for the farmers.	The results of the hydrological modeling and ex ante evaluation of several land use scenarios for the Fuquene watershed have been disseminated to the environmental authority. One of these scenarios consisted of changing traditional tillage practices to conservation farming practices (green manures, reduced tillage and direct drilling) that have been promoted during the last years by the environmental authority (CAR) and GTZ (Colombia). This scenario was selected by our project to be massively promoted through a financial mechanism because of its multiple benefits: erosion control, improvement of water soil retention, employment generation and improvement in farmer's income. Deapite of having been promoted by CAR and GTZ extension agents, the environmental and socioeconomic	

			impact of these practices were not measured before. Our project worked on measuring and disseminating these impacts to other potential partners.	
Regional Government of San Martin, EPSA (Water Supply and Sanitation Company of Moyobamba) and the PEAM project (GTZ-Regional Governement)	They decided to promote directly the development of a mechanism of payment for environmental services for conserving the upper catchments that supply water to the Moyobamba city. At the beginning, they were skeptical of the feasibility of the scheme. Also they had to go through a political process in order to receive the approval from the national government to be able to raise water rates for collecting payments from water users. This is the first case in Peru. This has resulted in a participatory process to obtain the authorization to increase water rates charges. It was necessary because by law, it is not possible to make increments on water charges without following a prior process starting in the National government and finally approved by the water users. With this the resources for a PES scheme are now ensured. Currently the PES scheme is under design.	The actors acquired knowledge that permit them to understand correctly the implications of a PES scheme and its usefulness to incentivize farmers to practice better management practices likely to reduce the production of sediments. Before this the actors thought that a PES scheme was a scheme to privatize the water resources.	The process started by the project, going from watershed analysis to dissemination and negotiation of a PES scheme, has resulted in the empowerment of local stakeholders that are now promoting this economic mechanism by themselves. The methodological approach and results from the hydrological modeling and the land use scenario analysis were disseminated with the actors to show in an anticipated manner the benefits of promoting land use changes in terms of sediment production reduction. Also the socioeconomic analysis demonstrated that for priority areas it was feasible to collect the payments needed to cover the opportunity costs of changing conventional slash-and-burn systems.	
Ministry of Environment - Peru	The Ministry of Environment has adopted the Altomayo PES case as an example to be replicated in Peru in other watersheds. Now they want to promote a PES scheme in a bigger watershed.	Knowledge on the institutional process carried out by the Altomayo case actors in order to receive the formal acceptation to create the fund.	Dissemination of the case at various scales, which includes the National scale represented for these matters by the Ministry of Environment.	

Farmers associations: CORPOMORTINO and ASOAGROALIZAL	New farmers have incorporated routinely conservation agriculture practices in their potato-based rotations. These farmers used to be restricted by the lack of enough machinery and capital required to make the technological change (from conventional to conservation agriculture). Through interviews conducted by the project, it was learned that farmers are aware that conservation farming is not just an alternative for increasing their income but also for reducing the amount of sediments moving downstream and getting deposited in the Fuquene Lake.	New attitude and skills with respect to conservation practices were developed by the farmers as the result of the technical assistance support provided by CAR and the financial incentives supplied by the project. Also the farmers associations have had to develop managerial skills to be able to manage successfully the revolving fund (since 2006).	The farmers associations are being benefited by the creation of a revolving fund for financing conservation farming practices in Fuquene watershed (Colombia). The direct beneficiaries are about 100 farmers per year. Also, as part of the strategy, the project has linked the operation of this fund with the technical assistance provided by CAR in order to ensure that conservation agriculture is practiced adequately.	
CORPOCALDAS, CORMAGDALENA and CAM (Watershed environmental authorities in Colombia)	Watershed planning is mandatory by law in Colombia and all environmental authorities must formulate their watersheds plans. Our methodological approach has been disseminated with the authorities and to date three of them (CAM, CORPOCALDAS and CORMAGDALENA) are using it for the formulation of these plans.	New knowledge was acquired by technicians of these organizations especially those related with hydrological modeling to prioritize areas for its contribution to regulate water flows and retain sediments. Also some of them were trained in the socioeconomic evaluation of land use alternatives using the ECOSAUT model.	During this process, we have been training local technicians and advising the environmental authorities' commissions in hydrological modeling and land use scenario analysis.	
GTZ- Peru (Piura)	In other Peruvian watersheds where GTZ is working, the tools developed by the project to analyze the hydrology and economic context of the watersheds have been adapted to provide inputs to design PES schemes. This is the case of the Gallega watershed located in Piura, Peru.	New knowledge was acquired by technicians of these organizations especially those related with hydrological modeling to prioritize areas for its contribution to regulate water flows and retain sediments. Also some of them were trained in the socioeconomic evaluation of land	The strategy has been doing together with the local technicians the hydrological and socioeconomic analysis as a means to create capacities while making the analysis reliant on their local knowledge of the study sites.	

		use alternatives using the ECOSAUT model.		
WWF-CARE-IIED	These organizations have incorporated in their PES design activities the results of the hydrological modeling and the land use scenarios analysis conducted by our team.	New knowledge was acquired by technicians of these organizations especially those related with hydrological modeling to prioritize areas for its contribution to regulate water flows and retain sediments. Also some of them were trained in the socioeconomic evaluation of land use alternatives using the ECOSAUT model.	An alliance between GTZ (our main partner) and WWF-CARE-IIED in Peru was created to train their technicians in the ECOSAUT model. At the same time they commissioned our project team to conduct the hydrological modeling of two watersheds in Peru where there was an interest to create a PES scheme. One of the watersheds was Jequetepeque, one of our study sites for which it was impossible for the project to acquire the climatic information. With this alliance the WWF-CARE-IIED provided this information needed for the hydrological modeling.	
Tungurahua Provincial Governement (Ecuador)	They have incorporated the results of the hydrological analysis and the competitiveness analysis in their discussions about how to recuperate the costs of operating a new reservoir and how to compensate the farmers that will be affected by the changes in the water supply for agriculture. Before this, they were planning to charge only farmers but with the analysis, other sectors are now considered.	New knowledge about the hydrological dynamics and water supply by the watershed and about analysis of how to quantify total benefits derived from land use changes. This includes concepts related with competitiveness, shadow prices, etc.	To conduct an analysis that simulated the hydrological flows and permitted to estimate the real water availability in the watershed and how this will change with storage in the new reservoir. Also the economic analysis helped to demonstrate that not necessarily the farmers will benefit the most from this infrastructure and that there are other actors that will receive benefits and as such should be incorporated in the cost-benefit sharing mechanism to be created by the provincial government.	

Of the changes listed above, which have the greatest potential to be adopted and have impact? What might the potential be on the ultimate beneficiaries? The change noted in Peru has a great potential as now the Ministry of Environment is aware of the feasibility of establishing PES schemes in Peru to ensure the regular provision of water. There are already evidences of this potential as now there are other initiatives by the Ministry and other organizations that are promoting the creation of these schemes based on the Altomayo experience. Also, the changes noted in the CAR and the farmers of the Fuquene watershed has great potential to be outscaled to other areas by demonstrating that not only payments, but other kinds of financial incentives such as soft loans are enough to promote the adoption of agricultural practices that have positive impacts on watershed services and farmer's income. This case should be brought to the agricultural national financial scheme in order to get more support for amplifying the mechanism and reach bigger scales. The project initiated contacts with representatives of the government in charge of creating financial incentives for farmers but still more work on policy change needs to be done. The change perceived in the representatives of the Tungurahua Provincial Government has high potential to influence the final political decision about how to recuperate the costs of the construction of the reservoir. The project has helped to raise awareness in the government about the benefits and costs that the construction of the reservoir represents for different actors, specially those derived from the intensification of agriculture downstream, the reduction of water flows in the upper part (as a result of the capture of water for filling up the reservoir), the increment in water supply for downstream water users, the increment of competitiveness for downstream farmers and the benefits derived from increasing the offer of agricultural products for Tungurahua town consumers.

What still needs to be done to achieve this potential? Are measures in place (e.g., a new project, on-going commitments) to achieve this potential? Please describe what will happen when the project ends. As mentioned above, in Peru the initiative of creating PES schemes has been taken up by the national environmental authority (Ministry of Environment) who is now promoting similar cases in the country. In fact one of these will be incorporated in a project during the second phase of the CPWF. In Fuquene, the same second phase project will assess the ex-post impacts of this project and expects to produce recommendations that can be taken effectively to the policy-makers to try to incorporate this kind of schemes in the financial system of Colombia for the agricultural sector, especially for those interested in practicing conservation agriculture. Also, the CAR continues committed to keep promoting conservation agriculture in the area as an alternative to reduce the production of sediments that are linked with the advanced eutrophication process of the Fuquene Lake. In Ecuador, the GTZ continues working closely with the Tungurahua Provincial government in the design of a scheme to share the costs and benefits derived from the construction of the reservoir.

Each row of the table above is an impact pathway describing how the project contributed to outcomes in a particular actor or actors. Which of these impact pathways were unexpected (compared to expectations at the beginning of the project?) Why were they unexpected? How was the project able to take advantage of them? The impact related to the changes achieved in some actors/organizations was

unexpected as they were not initially targeted as partners or intended users by the project. These are the Ministry of Environment in Peru, WWF-CARE-IIED in Peru and the Tungurahua Provincial Government (in relation with the construction of the reservoir). However the project took advantage of the opportunity of having them part of the impact pathway by considering these new actors as project output users and also as crucial actors for turning research results into actual decisions. The creation of partnerships with these actors has been crucial especially by founding these alliances on a partnership to link research with development. It is especially important when the local actors do not have the required technical and professional expertise to evaluate the possible impacts of PES-like schemes and therefore, to guide their design and implementation. On the other hand it is very usual that research project teams do not have the experience to influence policy makers who at the end are key actors for making viable this type of schemes. So these kinds of alliances permit to bring research results into the decision-making arena.

What would you do differently next time to better achieve outcomes (i.e. changes in stakeholder knowledge, attitudes, skills and practice)?

The project has been characterized by having an important influence on local decisions and as such on local interventions due to the important role that development partners as GTZ had in taking research results to decisions making processes and also by routing decisions maker's research questions to the project research team. However the project team considers that this collaborative scheme needs to be enforced in future projects by ensuring this in all watersheds having a strong interlocutor between decision makers and research team. In some sites this role was played by members of the research team, who already had research responsibilities and it was difficult to promote decision making changes in the desired intensity. Next time a clear interlocutor should be defined since the very beginning allocating the time and resources needed for ensuring this role in the project.

4 International Public Goods

Tools and Methodology

Model for environmental and socioeconomic ex ante evaluation of land use scenarios in watersheds – ECOSAUT. The model and its user manual was released in English and Spanish versions and are available in CD ROM. A printed Spanish version of the user manual is also available. The model can be applied to any watershed since it has been designed considering a wide range of possible variables that could affect water flows, sedimentation, cash flows, labor employment, and net income, among others.

A geo-referenced database of Hydrological Response Units for the five Andean study sites. For each Andean watershed the project is committed to identify the hydrological response units (HRUs) after integrating and analyzing the watershed soils, topography, land covers and climate. To date the project has identified the HRUs of the Fuquene watershed (Colombia), five sub-watersheds of Altomayo (Peru), Ambato watershed (Ecuador) and Jequetepeque watershed (Peru). In this database are included the hydrological reports which contain hydrological variables for each HRU. These reports are useful to determine the contribution of each unit to the hydrological externalities (water flows and sedimentation). All the GIS information is provided in CDROM to the CPWF.

Methodology. Publications describing the methodological approach (see section 6) are available

5 Partnership Achievements

The encouragement by the CPWF to create partnerships with local organizations was crucial to achieve project outcomes and to deliver research outputs of relevance for decision makers. The partnerships with local organizations and with development partners such the GTZ permitted to turn research results and recommendations into actual interventions in the study sites. This type of partnerships created to strenthen the relationship between Development and Research permitted, among others:

- To promote alternatives which are not currently supported by rural entrepreneurs (e.g. conservation agriculture with small farmers)
- Pilot implementation of the selected alternatives to detect potential constraints of massive implementation and verify the achievement of the expected impact (agroforestry systems in Altomayo (Peru), and conservation agriculture in Fuquene (Colombia))
- To create strategic alliances for R&D promoted by CONDESAN-GTZ and allowing face-to-face dialogue between local organizations, national authorities, international cooperation and international research centers.
- To promote crop and soil management changes that contribute to reduce the production of sediments and deposits of N and P into the Fuquene Lake.
- In general, the possibility of structuring a project based on R & D partnerships, where research support coming from CPWF was combined with development funds from project partners (GTZ and CONDESAN matching funds) was definitely crucial to explore financial mechanisms based on research results. Thus, the idea of exploring financial and economic schemes for promoting rural development based on the provision of better environmental services in the Andean watersheds has been facilitated by the research support provided by the project team and by the availability of the development matching funds.
- In the same sense, the type of research conducted in many of the project activities is only possible having the support of the CPWF, since the application of specialized methods like isotopes, greenhouses gases analysis, among others were expensive and not easily sponsored by development partners.

Apart from the advantages of having had a project founded on a R&D partnership, being part of the CPWF also implied other types of partnerships that facilitate the uptake of our methodological approach in other sites and by unintended users. Thus, being a CPWF project was a fact that facilitated our capacity to reach other potential partners and extrapolate our results and methods to other sites/unintended users. For example, Las Ceibas, Magdalena River and La Miel watersheds in Colombia under a collaborative agreement with the corresponding environmental authorities. Also with organizations such as WWF-CARE-IIED and CIFOR for which we conducted commissioned analysis and training to provide the basis for designing/evaluating PES schemes in Jequetepeque, Piura (Peru) and Pimampiro (Ecuador) watersheds, respectively. Also, the collaboration with the CPWF Project 20: SCALES, permitted to combine efforts in a common study site (Fuquene, Colombia) raising the efficiency of funds and time use. With the theme 2 team of the CPWF it was possible to train African professionals on the application of the ECOSAUT and SWAT models. With this, the project team wants to emphasize the importance to keep fostering research projects founded in partnerships with local stakeholders and ideally, next users.

6 Recommendations

- The use of a hydrological model such as SWAT has generated in most of the cases simulated series of which the trends fit well with measured values, and therefore, despite data limitations in the Andes, the SWAT model still permits to prioritize those HRU with higher incidence in water and sediment yields and to give an approximation of the magnitudes. Thus, although the model performance can still be improved by improving input data and adjusting the model for Andean conditions, the approach should be considered as valid and improvable through more field research for adjusting and validating the model. Thus, hydrological models are recommended as a powerful tool for targeting spatially the economic compensations in order to maximize the provision of the service.
- Gathering more detailed soil data will help to increase resolution when defining HRUs. In the Andes it is relatively easy to find good resolution of land use data but soil data is still general for small watersheds (1:100000). Thus, the efficiency of hydrological simulations in the Andes still needs to be improved by generating better input data, especially streamflow, daily rainfall and soil parameters, but this does not deprive us of the capacity to identify and prioritize the service providing units (HRUs).
- It is very common that hydrological models are calibrated using sensitivity analysis which identifies the variables that influence most on the resultant output values (i.e. water and sediment yield). In general these variables are modified in a ±10% range until the simulated results match well with measured values. So, it is recommended that sensitivity analysis for SWAT results should be run prior model calibration. This is especially feasible now that latest SWAT version includes this component to model. However when there are big differences between measured and simulated values in certain critical points this might be not the best procedure to adjust the model. In this sense the best practice is to understand which characteristics of the data and of the watershed may be causing these big differences that cannot be adjusted with conventional sensitivity analysis. This will not only enable the model user to obtain a better simulation but to improve his understanding of the watershed. This situation is very likely to occur in the Andes watersheds.
- For the economic assessment of land use alternatives and its impact on socioeconomic conditions of farmers, optimization models have demonstrated to be useful tools. However, the reliability of its results depends on quality data about benefits and costs of production systems, which is relatively easy to collect, information about default deforestation and other land-use change rates (incl. their fluctuations over time) used for scenarios analysis could critically affect incomes. Hence, this information in many cases needs to be refined in the Andes.

- The use of economic games was useful to understand the conditions under which the compensation may be feasible. However still some issues remained unanswered with this methodology. These are how the willingness to pay can vary with different amounts of payments (using real magnitudes in the game rather than symbolic numbers as used in the exercises) and to what extend and under what conditions the wealthiest farmers may participate in such payment schemes.
- The facilitation of dialogue and negotiation prior to the implementation of a PES-like scheme requires an important investment to cover consultations, applications of participatory methodologies, ex-ante analysis to know the magnitude of the service and the opportunity costs for implementing desired land uses, etc. This investment in this project, as in other PES schemes in Latin America, was covered by the donors (CPWF and GTZ) and was not charged to the created schemes. Although in theory it may be desirable that all those transactions costs should be included in the costs of the scheme, this may reduce its viability and for that reason these costs are commonly assumed by external parties (NGOs, governments, etc). This can continue being the situation in other cases of PES-like schemes and should be clearly recognized. Under these circumstances, it is important to raise the awareness and willingness of public sectors to promote these schemes as another tool for ensuring the provision of environmental services. Thus, all these up-front costs can be financed by the public sectors as part of their own agendas and as such, the implementation of these schemes will not rely only on the interest of external parties. This will still require strong efforts at the policy levels.
- The identification of win-win technological alternatives for improving the environmental and economic performance of conventional agricultural systems is essential. This may contribute to accelerate the process of negotiation by incorporating new incentives for the farmers beyond the mere payments (e.g. improvements on productivity and income). However the implementation of new technologies by small farmers may require PES-like subsidies as was the case in Fuquene, and as such PES-like schemes should be considered, as a complementary strategy in adoption processes of environmentally friendly agricultural practices.
- To finalize, as the poverty profiles demonstrated, the poorest in the Andes are those without land and therefore pro-poor PES schemes can be difficult to implement. In particular those schemes that pay for conserving natural areas will hardly favor these poorest households. Instead, PES schemes that promote better management practices may improve the conditions of the poorest if the new alternatives provide new sources of employment to landless inhabitants, change the availability of water during dry periods and improve accessibility to good quality water. This demands broader economic and social analysis in order to link all possible benefits derived from interventions promoted by PES-like schemes to the poor. This should at least include the multiplier effects of modifying income and employment through new land use alternatives, benefits derived from increasing water supply during dry periods and improving water quality by reducing soil erosion and water pollution.

7 Publications

Papers, posters and oral presentations for international seminar/ conference /workshop

Andean Watershed Project – CPWF PN 22. 2004. Sustainable Land Use in Andean watersheds "Andean Watersheds" Project. Poster presented at the Innovation Marketplace held during the Annual General Meeting AGM 2004 of the CGIAR. October, 2004. Mexico.

Estrada, R. & Quintero, M. 2005. Economic compensation for environmental services and its role in rural income equity. Fuquene (Colombia) and Altomayo (Peru) study cases. Presented at the Latin-American Symposium of Farming Systems (IESA-AL VI): The Valuation of goods and environmental services. Manizales, Colombia. July 20th, 2005

Estrada, R. & Quintero, M. 2005. Using Environmental Externalities to Generate Equito in Rural Income. From Theory to Practice. Case study: Fuquene Watershed (Colombia). Paper prepared and presented for the 18th Symposium of the International Farming System Association (IFSA) with FAO and IFAD. Rome, Italy. 31 October – 4 November 2005.

Moreno, A. 2007. Lessons learnt in PES schemes formulation. Oral presentation presented at the workshop of the project "Making Nature Count: enhancing payments for environmental service initiatives in Ecuador and Colombia" lead by CIFOR and Ohio University. The workshop was held in Ecuador on January 15-17, 2007.

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PROJECT PARTICIPANTS

The following persons were part of the research team or participated in the project as development partners. Their names are listed in alphabetical order.

Dr. Alonso Moreno – Project Leader – GTZ
Ana Maria Roldan – Student – Universidad Javeriana (Colombia)
Carla Gavilanes – Randi Randi Corporation (Ecuador)
Christine Bonn – GTZ (Peru)
CORPOMORTINO and ASOAGROALIZAL: Farmer's associations of the Fuquene watershed (Colombia)
Diana Maya – Sociologist – Universidad Javeriana (Colombia)
Diego Lopez – Extension agent – CAR (Colombia)
Doris Cordero – GTZ(Ecuador)
Dr. Edgar Amezquita – Soil Scientist – CIAT
Edwin Pajares – CEDEPAS (Peru)
Ernersto Giron – Research Assistant – CIAT
Fernando Aspajo – EPS (Water Supply Company of Moyabamba, Peru)
Fernando Lopez – Student – EPS (Peru)
Garin Garzon – Extension agent – CAR (Colombia)
Dr. Helle Munk Ravnborg – Principal Researcher - DIIS
Isabel Renner – Assistant - GTZ
John Serrato – Extension agent – CAR (Colombia)
Dr. Jorge Rubiano – Postdoctoral researcher – CIAT
Dr. Juan Camilo Cardenas – Economist – Universidad de los Andes (Colombia)
Kim Rabben – Student - DIIS
Ligia Ivette Gomez – Principal researcher – Universidad Centroamericana (UCA)
Marcela Quintero – Research Assistant – CIAT
Dr. Marco Rondon – Soil Scientist – CIAT
Marina Kosmus – GTZ (Ecuador)
Mauricio Proano – Randi Randi Corporation (Ecuador)
Mirella Gallardo – GTZ (Peru)
Natalia Uribe – Research Assistant – CIAT
Nelly Paredes – PEAM (Peru)
Dr. Olaf Westermann – Doctoral student - DIIS
Pablo Ramos – Student – Universidad Javeriana (Colombia)
Roberto Méndez – PROMIC (Bolivia)
Rodrigo López – PROMIC (Bolivia)
Roxana Velez – Communications assistant – GTZ
Ruben Dario Estrada – Project Co-leader- Principal Researcher – CONDESAN – CIAT
Washington Chapalbay – Indigenes representatives – Ambato watershed (Ecuador)
Wilson Otero – Extension agent – GTZ – FUNDESOT (Colombia)
Ximena Pernett – Research Assistant – CIAT

Appendix A

Abstracts of key publications:

Most project publications are in Spanish. Here are just presented some of them for different disciplines covered during the project. The reader is invited to know the whole set of publications in Spanish, many of them available at http://www.condesan.org/andean/index.shtml?i=EN.

For services rendered? Modeling hydrology and livelihoods in Andean payments for environmental services schemes

M. Quintero[a, *], S. Wunder[b], R. D. Estrada[a]

[a]*International Center for Tropical Agriculture (CIAT), A.A. 6713, Cali, Colombia*

[b]*Center for International Forestry Research (CIFOR), Convênio Embrapa-CIFOR, Tr. E. Pinheiro s/n, CEP66.095-100 Belém (PA), Brazil*

Abstract

In the Andes, demand for water is growing and upland land-use changes are increasing. Water quality, quantity and seasonal flow have thus also become environmental services with potential monetary value. Yet, currently the region's pioneer PES schemes are not paying for measured environmental services, but for proxy land uses thought to provide the(se) service(s). Hydrological modeling makes explicit the tacit causal relationships and tests underlying assumptions. Ideally, when combined with an economic analysis of land-use alternatives, this could inform decision makers on how much to pay for different interventions in different spatial locations. This paper focuses on two Andean watersheds: Moyobamba (Peru) and Pimampiro (Ecuador). In the first case, a municipal water company is preparing a payment for environmental services (PES) scheme to reduce upstream sediment loads. In the second, a similar conservation-oriented municipal PES scheme has operated since 2000, but the hydrological linkages have never been tested. Applying the Soil & Water Assessment Tool (SWAT), we identify in both watersheds biophysically critical areas for service delivery, and compare services for current land uses with change scenarios: deforestation, reforestation, live barriers, and agroforestry. We then use the ECOSAUT optimization model to predict net economic benefits for service providers. In Moyobamba, switching to shade-grown coffee would halve sediment yields, and increase significantly farmers' economic benefits. This requires high up-front investment, but the willingness to pay of water users in Moyobamba town may suffice to cover the upfront costs. In Pimampiro, resumed deforestation would increase sediments by >50% and reduce dry-season flow by 0.5%, thus reinforcing the rationale of the existing PES scheme, focused on conserving native forests and grasslands.

Multiscale Analysis for Promoting Integrated Watershed Management

Jorge Rubiano[a], Marcela Quintero[b], Ruben Dario Estrada[c], Alonso Moreno[d]

[a]*Postdoctoral Fellow, Land Use Project, International Center for Tropical Agriculture (CIAT), A.A. 6713, Cali, Colombia*

[b]Research Assistant, CIAT - Consortium for the Sustainable Development of the Andean Region (CONDESAN), A.A. 6713, Cali, Colombia

[c] Senior Researcher, CIAT - CONDESAN, A.A. 6713, Cali, Colombia

[d] *Project "Cuencas Andinas" GTZ/CONDESAN, International Potato Center (CIP), PO Box 1558, Lima 12, Peru*

Abstract

The ongoing experience of a project implemented by the Consortium for the Sustainable Development of the Andean Region (CONDESAN) in the Fúquene watershed of Colombia is presented. Biophysical and socioeconomic knowledge is integrated in a complex process to offer sound solutions to a wider range of stakeholders affected by the eutrophication of Fúquene Lake. A multiscale analysis is carried out for every step of the process to warrant integrity in the use of information, inclusion and equity in the stakeholders' participation.

The ultimate aim is to generate sustainable development processes in the rural sector. By focusing on the internalization of externalities derived from watershed management, transfers of funds from urban to rural populations are stimulated, triggering urban investments in rural environmental goods and services.

The process starts integrating key spatial information, which is available at different scales for the site, in order to facilitate envisioning different land-use scenarios and their impacts upon water resources. Subsequently, selected alternative scenarios regarding the impact on the externalities identified are analyzed, using optimization models. Opportunities for and constraints to promoting cooperation among users are identified, using economic games in which more sustainable land-use or management alternatives are suggested. Strategic alliances and collective action are implemented in order to test the feasibility of environmental and economic alternatives. Their implementation is supported by co-funding schemes designed with private and public stakeholders having a role in the study area. Research needs and limitations of the methodology are discussed.

A Manual for ECOSAUT: A Model for the Economic, Social, and Environmental Evaluation of Land Use

Quintero, M., Estrada, R.D. and Garcia, J.

International Center for Tropical Agriculture (CIAT), A.A. 6713, Cali, Colombia
Consortium for the Sustainable Development of the Andean Region (CONDESAN)

Projects on natural resource management are oriented towards preserving and/or restoring the ecological functions of ecosystems as one way to ensure adequate levels of environmental goods and services. Hence, watershed analyses are focusing on understanding the causal relationship between land use and associated technologies and their effects on water quality and quantity. Understanding this relationship is emphasized because most environmental conflicts in watersheds arise from protests of those affected by sedimentation, water deficits during dry times, increased floods, and reduced potability of water.

Recently, the Policy Analysis Section of the Consortium for the Sustainable Development of the Andean Ecoregion (CONDESAN) studied externalities related to hydrologic dynamics as a priority axis on which to generate new dynamics of rural development in the mountains of the Andean Region, South America. These new dynamics will be initiated through transfers of capital from urban to rural sectors, which will be justified by positive changes in the supply of environmental goods and services from these watersheds.

Since 2003, CONDESAN's initiative, formally constituted as the Regional Project—Andean Watersheds, has been supported by the German Agency for Technical Cooperation (GTZ). One objective of this project is to develop and apply capabilities related to watershed analyses that will support decision makers on changes in land use and management practices that will generate positive externalities. This project is being executed in the Andean ecoregion, which include the watersheds of Colombia, Ecuador, and Peru.

With this purpose, the Andean Watersheds Project seeks to strengthen watershed analyses to permit suitable interventions in these areas through joint investment schemes. One way of supporting these analytical processes is to develop tools and methodologies that can be used in watersheds by all the Project's local partners. One tool is the model being presented here, which permits, among other things, the *ex ante* evaluation of the impact of changes in land use on hydrologic externalities and the socioeconomic status of a watershed's inhabitants.

This document aims to illustrate and facilitate the management of the model *Economic, Social, and Environmental Evaluation of Land Use* (ECOSAUT, its Spanish acronym) by users interested in integrated watershed analyses. The design of both the model and this manual is directed towards professionals involved in natural resource management and who understand environmental economics.

The manual's structure is based on three principal parts: (1) a description of the model, (2) an explanation of its use, and (3) an exposé of its structure and functions. This document should be read while accessing the model's Excel files to better comprehend the explanations. The model's operation and structure will be described with reference to each of the Excel spreadsheets composing it. Although the model contains information corresponding to that used in the manual's examples, it is valid only for academic purposes. Hence, if users wish to use the model for their own purposes, they need to initialize it.

Integrated Watershed Management: The experience of the Andean Watersheds Project

Moreno, A. and Renner, I. (Eds)

GTZ

Abstract

The Andean Watersheds Project of the GTZ last 3 years and was the counterpart of the PN22 project of the Water & Food Challenge Program. The overall goal of this project was "Actors in the selected watersheds use the environmental externalities to prioritize and implement sustainable development project". The beneficiaries of the projects were technicians and decision-makers from municipalities, development and research projects, local NGOs and poor population of the watersheds. Many of the accomplishments of the AWP are the results of the collaborative and join effort with the PN22 project of the CPWF. Thus this publication compiles the results of the studies conducted and the direct interventions made in the studied watersheds. It also describes the lessons learned and the successes and failures during the project. This is especially important because the AWP was a development project fed by research outputs of the PN22, a link not very common in research and development projects. The document structures permit to the reader go to independent chapters but putting each of them in the context of the chain of steps followed by the project: Watershed analysis-prioritization of areas and actions-planning-intervention-monitoring-evaluation.

Poverty, access and payment for watershed hydrological services. A social feasibility study with case in Tiquipaya watershed, Bolivia.

Olaf Westermann

Department of Environmental, Social and Spatial Changes – Roskilde University Centre
Natural Resources and Poverty – Danish Institute for International Studios (DIIS)

Abstract

Recently a new type of conservation project has entered the 'conservation and development' scene, the so called payment for environmental service schemes (PES). PES schemes seek to integrate protection of environmental services like watershed services with poverty alleviation by setting up schemes where beneficiaries, e.g. downstream urban populations and industries or international organizations, pay or compensate natural resource managers/land users, often poor rural farmers, for the protection of environmental services. In theory this is an appealing idea that increasingly has been endorsed by local authorities and national and international development organizations. The challenge is that PES schemes are not poverty alleviation tools per se. The principal objective of PES schemes is to conserve and/or generate desired environmental services which do not necessarily coincide with poverty alleviation. At the same time PES schemes are often set up in contexts of competition and struggle over natural resources which determine whether and how the process of PES negotiations take place. Khora Tiquipaya watershed is, among other watersheds in the Cordillera del Tunari, the principal source of water for both consumption and agricultural production in Cochabamba, Bolivia. At the same time, these watersheds regulate the flow of water and torrents in streams and rivers determining the risk of flooding in the valley. Unfortunately, human intervention has led to large scale degradation of the watersheds resulting in lower recharge of aquifers and a decrease in groundwater availability as well as an increase in flooding damaging agricultural production and infrastructure in the valley. The watersheds are also characterized by extreme poverty (90% of the rural population) and, particularly in the case of Tiquipaya, by numerous struggles and conflicts over access to and control over water resources. On basis of the situation of poverty and environmental degradation in the Cordillera del Tunari and considering the struggles and conflicts over access to and control over water resources in the Khora Tiquipaya watershed, this thesis explores the conditions under which pro-poor payment for watershed hydrological services schemes (PWHS) is feasible in the Khora Tiquipaya watershed. Specifically, the thesis looks into (i) whether and to what extent water

access and control relations is likely to influence the negotiation of PWHS schemes in the Khora Tiquipaya watershed and vice versa, and (ii) what the consequences for the poor of implementation of PWHS schemes and what their options and capacities for participating in these as service providers are. To understand water access and control relations and struggles in Khora Tiquipaya watershed the thesis combines Ribot and Peluso's analytical framework and inclusive understanding of access as both rights based, social and structural, with Bourdieu's praxeology that sees social life as being a result of struggle in a social field of power relations. Ribot and Peluso's analytical framework helps to operationalize the particular field of access and control over water resources in Tiquipaya while a stakeholder analysis, based on interviews with key actors with contrasting views, is used as a tool for empirical data collection and analysis. The dimensions and levels of poverty in the Cordillera del Tunari, including Khora Tiquipaya watershed, are examined on the basis of local perceptions and an extensive questionnaire survey. This study finds that there are opportunities for implementing pro-poor PWHS in Tiquipaya. Land tenure is secure also for the poor (allowing long term conservation investments) and organization strong and inclusive (minimizing transaction costs of payment to numerous small-scale farmers and allowing the poor to participate on equal basis). It is suggested that pro-poor PWHS schemes will be most effective using an asset-building/in-kind payment approach, e.g. in the form of capacity building to improve agricultural production in combination with a system of continuous payments. At the same time there is a need to scale up payments schemes to the entire Cordillera del Tunari to establish a regional support group/fund that could can help to resolve the economic constraints inherent in local payments schemes. However, to assess the feasibility for implementing pro-poor payment schemes it is necessary also to understand the potential interaction that will occur between the implementation of pro-poor PWHS and the established field of water access and control. Because, following Bourdieu and Long, the power relations in a field inevitably will interact with, in this case, the implementation of PWHS. How these power relations influence the social feasibility of the implementation of PWHS depends on how PWHS schemes affect the content and boundaries of the field i.e. how PWHS schemes changes the values and the different actors' capital based position in the field, because such changes will influence their points of view on PWHS schemes. The analysis shows that the negotiation and implementation of PWHS schemes in Khora Tiquipaya is likely to change the dynamic of the social field not only because it changes communications among the actors in the field, particularly among the irrigation farmers and drinking water committees, but also because it changes who the players are and what their positions in the field are. Particularly it strengthens upstream farmers' voice in the field and allows external actors like NGOs a stronger position in the field. The implementation of PWHS schemes is also expected to contribute to changing the values in the field increasing recognition of payment as a valid form of compensation or retribution. PWHS schemes are likely to add to the repertoire of means upon which upstream farmers claim access to water resources (Cruzani community) or claim benefit from other actors' (particularly irrigation farmers) access to water resources (Totora community). Due to the changes in the objective relations of positions, values and upstream farmers' diverse claims in relation to water resources it is likely that the dominant stakeholders in the field, particularly the irrigation farmers, will feel that their position in the field will be threatened. As a result, the implementation of pro-poor PWHS schemes is only feasible if the position of the irrigation farmers and their organization, ASIRITIC, in the field, is recognized and they are included in the negotiations from the start.

Effects of Conservation Tillage in Carbon Sequestration, and Net Revenues of Potato-based Rotations of the Colombian Andes.

Marcela Quintero

University of Florida, Soil & Water Sciences Department

Over 60% of the world's carbon is held in both soils (more than 41%) and the atmosphere (as carbon dioxide; 20%)). However, soil disturbance is redistributing the carbon, augmenting the atmospheric carbon pool. Thus, a part of carbon dioxide increase in the atmosphere is thought to come from agriculture, affecting not just climate change but also productivity and sustainability of agriculture and natural resources. This study was undertaken to investigate the contribution of conservation tillage practices in potato-based rotations of the Fuquene Lake watershed in the Colombian Andes, to reduce Greenhouse Gases (GHG) emissions, sequester soil carbon, to rehabilitate water and carbon-related soil characteristics, and to understand the opportunity costs of changing from conventional to conservation tillage. Field soil sampling was conducted in 7-years old conservation tillage farms and in farms with conventional tillage practices. Soil samples were

analyzed in the lab to determine Soil Organic Carbon stocks, SOC in soil aggregates by applying ultrasound, and water-related physical characteristics. In addition GHG net emissions were calculated for conservation and conventional tillage, and contrasted with net revenues. As a result, conservation tillage in potato-based systems improved in a 7 year period the soil organic matter and carbon content in these disturbed soils. The soil carbon concentration in the whole profile was 29% higher under conservation tillage than under conventional tillage sites and the carbon content was higher by 45%. C content improvement specially occurred in the subsoil (A2 horizon) increasing by 177% although most of the C is stored in the top A1 horizon. This improvement was correlated to the enhancement of soil physical characteristics related with soil water movement and storage such us bulk density, AWC, saturated hydraulic conductivity and mesoporosity. In another hand OM in aggregates represented more than 80% of total OM of these soils and was positively affected by conservation tillage. This improvement showed a preferential C sequestration in smaller macroaggregates (<2 mm). The aggregate dispersion energy curves further suggest this is happening in microaggregates within the smaller macroaggregates fraction. A complementary tradeoff between the economic and environmental benefits was found for our study site. This relies on the fact net farmer revenues were increased —by reduced machinery operations and fertilizers applications—, while GHG emissions were reduced –by increasing soil carbon retention and reducing GHG emissions from machinery operations—. Thus, although conservation tillage practices are not widely adopted in the watershed, payments for net GHG removals could increase more the net revenues and facilitate the investment to cover initial extra costs of conservation agriculture (ie. cultivation of oat as cover crop).

Analysis of poverty profiles in the Tunari Mountains: Pro-poor options for the implementation of payments for watershed services.

Olaf Westermann[1], Patricia Arévalo de la Zerda[2]

[1]Danish Institute for International Studies, DIIS

[2]International Center for Tropical Agriculture, CIAT

The main objective of this research work was to identify the well-being levels in the communities located in the Tunari Mountains (Bolivia) by means of building local profiles of poverty based on local well-being perceptions. The ultimate purpose is to be able to analyze the relationship between poverty and access and management to and of natural resources. The analysis is essential for the discussion about the implementation of payment for watershed services schemes (PWSS) to alleviate poverty. The results of the study show that there are opportunities to integrate this kind of economic schemes with poverty alleviation. The land tenure is secure even the lands of poor permitting to make long-term investments for the conservation of ecosystem services. Also the social organization is strong and inclusive diminishing the transaction costs of making payment to several small farmers and allowing them to participate in equal terms. However, due to the very small size of the land properties (50% of the poor own less than 0.25 ha and 23% do not own land) and the lack of economic resources to implement new agricultural practices it is proposed that pro-poor PWSS could be more efficient if: 1) the payments are given as an in-kind compensation or retribution like training on new agricultural technologies; 2) new employment opportunities are created when PWSS are setting up and there are payments in advanced in order to cover the up-front costs of conservation activities. All of this combined with a permanent system of payments to ensure the conditionality of the scheme.