CPWF Project Report

Socioeconomic and Technical Considerations to Mitigate Land and Water Degradation in the Peruvian Andes

Project Number PN70

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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 water productivity for agriculture—that is, to change the way water is managed and used to meet international food security and poverty eradication goals—in order to leave more water for other users and the environment.

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

Socioeconomic and Technical Considerations to Mitigate Land and Water Degradation in the Peruvian Andes

This project aims to increase agricultural productivity, incomes, and sustainable management of land and water by small farmers in the rural Sierra region of Peru. Although results demonstrate the effectiveness of increased productivity and commercialization of high value agricultural commodities, this type of activity may be limited to certain parts of the watershed with access to irrigation and startup capital. Interventions promoting commercialization, such as those of CEDEPAS Norte, may result in reduced soil degradation and decreased conversion of pastures to cropland. On the other hand, the evaluation results for PRONAMACHCS indicate how difficult it is to improve the standard of life of the population by focusing exclusively on soil and water conservation techniques. Thus, this analysis indicates that a combination of activities may be necessary in order to improve productivity in the short term and promote adoption of sustainable soil and water conservation techniques in the medium and long term.

CPWF Project Report Series

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RESEARCH HIGHLIGHTS

Land and water degradation are severe problems in rural areas of the Andes, undermining agricultural productivity, contributing to high levels of poverty and food insecurity, and causing major problems for downstream users of land and water resources. Most of the poor live in degraded areas where agricultural production on very steep slopes and limited use of sustainable land and water management technologies are causing major degradation and low productivity. Despite recovery of the economy of Peru since 2000, low agricultural productivity in the Sierra region, due in part to land degradation, is inhibiting the ability of people in this region to take full part in this growth. Consequently, increasing the productivity and commercial value addition of agriculture in the Sierra in a sustainable way is a high priority for the government of Perú.

Although much research has been conducted or is ongoing related to land and water degradation in the Jequetepeque watershed, most of this research is biophysical in nature and little is known about the quantitative impacts of the adoption of management practices on agricultural productivity, poverty, or land degradation. Supported by the Challenge Program for Water and Food (CPWF) of the Consultative Group for International Agricultural Research (CGIAR), this project studies the conditions required for widespread adoption of sustainable land and water management technologies in the Jequetepeque basin while ensuring relevance of the results for similar regions elsewhere in the Sierra.

The findings from the impact analysis support the strategy of the Peruvian government and various NGOs to promote the development of the rural Sierra by identifying and promoting higher value activities linked to regional and local market development and comparative advantages. Such efforts can pay off, as the projects of the Centro Ecuménico de Promocción y Acción Social (CEDEPAS Norte) are apparently doing in Payac (project to promote organic methods of fruit production and commercialization in the micro-watershed of the Payac River, in San Miguel province) and Chetilla (project designed to promote livestock and pasture improvement in Cajamarca province), if appropriately targeted and responsive to farmers' needs by incorporating both natural resource management and sustainable rural economic development. Evidence from the less successful PRONAMACHCS (the Programa Nacional de Manejo de Cuencas Hidrográficas y Conservación de Suelos) government interventions in the Contumazá province (program promoting reforestation and soil and water conservation but not economic development) shows that a different approach is needed. More effort is needed to identify and promote technologies in the near term while encouraging shifts to more sustainable and remunerative land uses and livelihood options for poor people living in such fragile environments. All three projects evaluated also show a high dependence of the producer organizations on the external agency support and guidance. This approach appears to be insufficient, and the problems generated by the organization's lack of internal institutionalization seem to be at the heart of the project's sustainability once the external agent retires from the area.

Findings from the tradeoff analysis help evaluate the adoption rates of the alternative interventions. This analysis shows that in the case of Contumazá, on average, farmers are actually worse off when adopting but the alternative practice is still worthwhile for 25% of the farms. In the cases of Payac and Contumazá where the interventions resulted in (on average) higher per capita incomes, almost 65% of the farmers are benefitting from the alternative practice. However, the shapes of the adoption curves for Contumazá and Chetilla are very different. In the case of Chetilla, the benefits are relatively small compared to Payac, which may result in farmers acting conservatively and avoiding the risks associated with changing practices. In the case of Chetilla, a relatively small incentive could lead to very high adoption rates as the alternative practice will become profitable for all farmers. In the case of Payac and Contumazá much higher incentives are necessary to make the alternative practices profitable. Although major differences in soil quality are not observed, probably due to the relatively recent adoption of practices, long term effects may still improve soil quality, reduce erosion, and increase productivity.

Finally, the institutional analysis shows that the Payac intervention has been successful in promoting entrepreneurial attitudes amongst beneficiaries, resulting in increased confidence in their ability to improve their own economic situations. Analysis of the Contumazá intervention, on the other hand, suggests that PRONAMACHCS' use of donations to promote conservation may have lead to a failure to convince its beneficiaries of the importance of conservation practices. An examination of the Chetilla intervention shows that, in part due to a secure milk market and strong constant leadership, APROGAL is a strong organization with the ability to enforce its own rules.

EXECUTIVE SUMMARY

Land and water degradation are severe problems in rural areas of the Andes, undermining agricultural productivity, contributing to high levels of poverty and food insecurity, and causing major problems for downstream users of land and water resources. These problems are acute in the rural Sierra of Perú. More than 50% of the land in the Peruvian Sierra is considered degraded or severely degraded, and four out of five of the 9 million inhabitants of this region are poor. Most of the poor live in degraded areas where agricultural production on very steep slopes and limited use of sustainable land and water management technologies (SLWMT) are causing major degradation and low productivity. Despite recovery of the economy of Peru since 2000, low agricultural productivity in the Sierra region, due in part to land degradation, is inhibiting the ability of people in this region to take full part in this growth. Consequently, increasing the productivity and commercial value added of agriculture in the Sierra is a high priority for the government of Perú.

These problems are particularly evident in the Jequetepeque River watershed in northern Perú. Extending from the Pacific Coast to the summit at nearly 4,200 meters above sea level, this watershed is a site of high population pressure, poverty and severe land degradation. Many farmers produce subsistence crops on very steep slopes with very limited use of soil and water conservation measures. Deep gullies and landslides mark much of the upper watershed, and sediment flows into the rivers have been responsible for rapid sedimentation of the Gallito Ciego reservoir, site of an important hydroelectric dam and source of irrigation water for the lower watershed.

Because of these problems, substantial efforts are being made to promote improved land and water management in the Jequetepeque watershed. Many government and non-governmental organizations (NGOs) are operating projects in the watershed, intended to improve natural resource management and increase rural incomes. Many research efforts are also underway in the watershed, including research led by partners in the Challenge Program for Water and Food (CPWF). Although much research has been conducted or is ongoing related to land and water degradation in the Jequetepeque watershed, most of this research is biophysical in nature. Despite the many projects and organizations operating in JW, little is known about their quantitative impacts on adoption of SLWMT or on agricultural productivity, poverty, or land degradation.

The widespread use of degrading land and water management practices in the Andean system of basins constitutes a significant bottleneck to achieving sustainable agricultural growth. However, there exist sustainable land and water management practices that can be profitably adopted by farmers once appropriate economic, social, technical, and institutional frameworks are in place. This study was conducted to help address this knowledge gap in order to contribute to improved land and water management in the Jequetepeque watershed and similar contexts elsewhere in the

Andes. Supported by the Challenge Program for Water and Food (CPWF) of the Consultative Group for International Agricultural Research (CGIAR), the project studied the conditions required for widespread adoption of sustainable land and water management technologies in the Jequetepeque basin while ensuring relevance of the results for similar regions elsewhere in the Sierra.

Working closely with local governments, communities, and farmers' and technical assistance organizations, the project collected and analyzed household survey data along with biophysical data in order to better understand key factors affecting adoption and analyze the costs, benefits and tradeoffs of specific management options and the interventions promoting them. Using biophysical data and a geo-referenced household survey of the region, the stochastic profit frontier approach was used to construct a typology to estimate the profit efficiency for the Jequetepeque watershed. By estimating the efficiency levels of local farmers and rural workers, regional potential and bottlenecks can be identified and used to highlight priority areas from which to select possible interventions as well as a way to scale up the interventions once they had been properly evaluated and had been successful in resolving the bottleneck they were design to resolve.

The selection of interventions and sites focused on the critical areas highlighted in the typology (critical areas had high levels of poverty and included zones of both high and low agricultural potential) and also took into consideration the importance of land and water management in the middle and upper watershed for the availability and quality of water in the lower watershed. Household survey data was collected on a variety of topics including household characteristics, assets, land management and use, and technical assistance, among others. Soil samples were also collected from intervention areas as well as geographic coordinates, altitude, and area for each household's most important parcel. Data was then used to determine the impacts of the 3 project interventions, conduct an institutional analysis of the intervention areas, and create a minimum data tradeoff analysis model to analyze the adoption of soil and water conservation practices.

The findings from the impact analysis support the strategy of the Peruvian government and various NGOs to promote the development of the rural Sierra by identifying and promoting higher value activities linked to regional and local market development and comparative advantages. Such efforts can pay off, as they are apparently doing in Payac and Chetilla, if appropriately targeted and responsive to farmers' needs. Evidence from the less successful PRONAMACHCS interventions in the Contumazá province shows that a different approach is needed. More effort is needed to identify and promote technologies in the near term while encouraging shifts to more sustainable and remunerative land uses and livelihood options for poor people living in such fragile environments. In addition, in all three projects evaluated, a high dependence of the producer organizations on the external agency support and guidance was evident. This approach appears to be insufficient, and the problems generated by the organization's lack of internal institutionalization seem to be at the heart of the project's sustainability once the external agent retires from the area.

Because of the high level of variability in agroecological conditions in the Jequetepeque watershed, it is difficult to evaluate whether different interventions are applicable in other parts of the watershed. This analysis provides a methodology to quickly screen for comparable agro-ecological conditions on the basis of readily available digital elevation models and remote sensing images that help to find areas of comparability. The tradeoff analysis was also implemented in order to evaluate the adoption rates of the alternative interventions. The analysis shows that due to the large variation in farming conditions, the interventions are only paying off for 65% of the farmers. In Contumazá, the opposite is true: on average, farmers are actually worse off when adopting but the alternative practice is still worthwhile for 25% of the farms. Although major differences in soil quality were not observed, probably due to the relatively recent adoption of practices, long term effects may still improve soil quality, reduce erosion, and increase productivity.

The institutional analysis shows that the Payac intervention has been successful in promoting entrepreneurial attitudes amongst beneficiaries, resulting in increased confidence in their ability to improve their own economic situations. Analysis of the Contumazá intervention, on the other hand, suggests that PRONAMACHCS' use of donations to promote conservation may have lead to a failure to convince its beneficiaries of the importance of conservation practices. An examination of the Chetilla intervention shows that, in part due to a secure milk market and strong constant leadership, APROGAL is a strong organization with the ability to enforce its own rules.

INTRODUCTION

Land and water degradation are severe problems in rural areas of the Andes, undermining agricultural productivity, contributing to high levels of poverty and food insecurity, and causing major problems for downstream users of land and water resources. These problems are acute in the rural Sierra of Perú. More than 50% of the land in the Peruvian Sierra is considered degraded or severely degraded, and four out of five of the 9 million inhabitants of this region are poor. Most of the poor live in degraded areas where agricultural production on very steep slopes and limited use of sustainable land and water management technologies (SLWMT) are causing major degradation and low productivity. Despite recovery of the economy of Peru since 2000, low agricultural productivity in the Sierra region, due in part to land degradation, is inhibiting the ability of people in this region to take full part in this growth. Consequently, increasing the productivity and commercial value added of agriculture in the Sierra is a high priority for the government of Perú.

The economic and environmental problems of the Sierra region are particularly evident in the Jequetepeque River watershed in northern Perú. Extending from the Pacific Coast to the summit at nearly 4,200 meters above sea level, this watershed is a site of high population pressure, poverty and severe land degradation. Many farmers produce subsistence crops on very steep slopes with very limited use of soil and water conservation measures. Deep gullies and landslides mark much of the upper watershed, and sediment flows into the rivers have been responsible for rapid sedimentation of the Gallito Ciega reservoir, site of an important hydroelectric dam and source of irrigation water for the lower watershed.

Because of these problems, substantial efforts are being made to promote improved land and water management in the Jequetepeque watershed (JW). Many government and non-governmental organizations (NGOs) are operating projects in the watershed, intended to improve natural resource management and increase rural incomes. Many research efforts are also underway in the watershed, including research led by partners in the Challenge Program for Water and Food (CPWF). Although much research has been conducted or is ongoing related to land and water degradation in the Jequetepeque watershed, most of this research is biophysical in nature. Despite the many projects and organizations operating in JW, little is known about their quantitative impacts on adoption of SLWMT or on agricultural productivity, poverty, or land degradation.

This study was conducted to help address this knowledge gap in order to contribute to improved land and water management in the Jequetepeque watershed and similar contexts elsewhere in the Andes. Far from being homogenous, the Sierra consists of a wide variety of "micro-regions" which are affected by various underlying structural problems that keep them from benefitting from economic growth remain in differing ways and degrees. A "one-size-fits-all" solution cannot succeed in such a region. Using mapping technology and a variety of data to divide the Sierra into micro-regions that differ according to their characteristics, problems, and potential for development, Maruyama and Torero (2007) developed a typology based on relevant criteria, including climate and topography, production, access to roads and markets, off-farm job opportunities, population density, gender distribution and the presence of various institutions, such as credit providers. These and other conditions indicate which structural problems will affect a particular micro-region and how. Using this typology for Perú along with additional data collected for this project, it is possible to zoom in on the Cajamarca region and focus specifically on the Jequetepeque watershed to determine the different types present in the area according to welfare measures and profit efficiency levels. Understand the bottlenecks associated with these types will then help determine the investments necessary as well as the types of interventions likely to succeed in reducing poverty.

The Jequetepeque Watershed

This research was conducted in the Jequetepeque watershed of northern Peru in the western Andes mountain range. The watershed is situated in the departments of Libertad and Cajamarca and includes 6 provinces and 45 districts. The Jequetepeque watershed is located between 6°48’ and 7°30’ southern latitude and 78°22’ and 79°41’ western longitude and covers 5,136 km2. The altitude of the watershed varies from 0 to 4,188 meters above sea level (masl). Mean annual precipitation ranges from under 200 mm in the coastal areas to between 500 and 1,100 mm in the upper part of the watershed.

The Jequetepeque watershed can be divided into three zones by elevation: the upper watershed, which is located above 600 masl with steep slopes and semi-arid to sub-humid peri-glacial climates; the middle watershed, which is located from 225 to 600 masl and includes moderate to steep slopes with arid and semi-arid climates; and the lower watershed, which is located from 0 to 225 masl and includes desert slopes and alluvial plains. The upper watershed is characterized by pastures, forested areas, and some cultivation of crops (mostly barley, wheat, potatoes, maize, fruit, and peas), although the steep inclines make crop production difficult in this zone, exposing the soil to severe erosion and problems of landslides and gullies. The largest gold mine in South America is located in the highest part of the upper watershed, causing water pollution as well as exacerbating erosion problems. The middle watershed is dominated by maize, sugarcane, fruit, and pastures, and milk production exists in the higher altitude areas as well. The main crop in the lower watershed is rice, all of which is irrigated, which causes salinization problems in this zone. Gallito Ciego, the 34 MW hydroelectric dam built in 1987, provides irrigation for 36,000 ha in the lower part of the watershed, where the lack of precipitation makes all agricultural activities nearly impossible without irrigation. This study focuses on interventions in the mid to upper Jequetepeque watershed because problems of land degradation and poverty are greatest in this zone. Most inhabitants in the lower watershed enjoy much higher levels of well-being than those living in the rest of the watershed.

According to the 2005 census, approximately 390,000 people live within the Jequetepeque watershed, of which 47% live in rural areas and 53% in urban areas. Although there is a rough balance between the urban and rural population of the entire watershed, the population is predominantly rural in the upper watershed. In the lower watershed, 81% of the population lives in urban areas, whereas in the highlands, 80% of the population lives in rural areas (Goméz et al. 2005, p. 8). Approximately 25% of the population lives below the poverty line, and education levels are low, especially in the middle and upper watershed. Average per capita income in the watershed is approximately US $700. According to the National Statistics Institute (INEI), 47% of Jequetepeque's inhabitants are involved in agricultural and livestock activities, with the remainder working in mining, manufacturing, building, tourism and related activities, services, trade, and teaching.

The Jequetepeque watershed is plagued by problems of soil erosion, rapid sedimentation of the reservoir, salinization, and other land and water degradation. The expansion of agriculture in the watershed, especially in the steeply inclined areas in the upper watershed, unsustainable agricultural practices, and inefficient water use have led to serious erosion problems and have severely diminished the capacity of the Gallito Ciego dam as a result. It is estimated that between 1987 and 1997, 40 million m3 of solids came into the reservoir, while in 1997 and 1998, 60 million m3 of solids entered due to the effects of El Niño (CGIAR Challenge Program on Water and Food/CONDESAN: Andean System of Basins: Watershed Profiles, November, 2007). By 2000, sedimentation in the reservoir had reduced its useful capacity by nearly 10% (Sanchez, undated). Although much of the erosion and sedimentation may be caused by geological activity and poorly constructed and maintained roads, agriculture also appears to be a major source of the problem. According to one recent study modeling land and water use and erosion in JW, erosion rates exceeding 20 tons per hectare per year (well in excess of soil formation rates) are found in many areas of the watershed cultivated with annual crops or used for seasonal pasture (López and Girón 2007). Salinization of coastal soils is also an increasing problem in the Jequetepeque watershed resulting from irrigation practices and drainage issues in the lower watershed. Agrochemicals, mining activities, and sewage from urban centers along the river basin are also continuously adding contaminants to the rivers in the watershed and creating additional pollution issues and further degradation of the watershed.

Because of these problems, substantial efforts are being made to promote improved land and water management in the Jequetepeque watershed. The regional government of Cajamarca department and municipal governments within the watershed are operating and planning numerous programs to improve livelihoods and natural resource management. The six provinces and 29 municipalities in the watershed have joined forces to form a coordinating body, the Coordinadora de la Cuenca Jequetepeque, to coordinate actions to improve management of the watershed and people's welfare. An Autoridad Autonoma is responsible for managing the supply and use of water to the Gallito Ciega dam. Many government and non-governmental organizations (NGOs) are operating projects in the watershed, intended to improve natural resource management and increase rural incomes.

The Programa Nacional de Manejo de Cuencas Hidrográficas y Conservación de Suelos (PRONAMACHCS), a program of the Ministry of Agriculture, has carried out numerous projects relating to watershed management, natural resource management, and agricultural production in the watershed since the late 1990s. It promotes practices oriented towards soil and crop management with the idea of reducing risk of erosion and improving the productive capacity of the soil, including contour furrows and strips, crop rotation, crop association, organic and chemical soil modifications, cover crops, minimum tillage, and irrigation. PRONAMACHCS also provides assistance in more technical methods of land management including practices designed using engineering principles to reduce erosion by controlling hillside surface erosion, either modifying the slope of the hill or reducing the inclination of the hill. Some of these interventions include terraces, infiltration ditches, dike construction, and contour ridges.

The Centro Ecuménico de Promocción y Acción Social (CEDEPAS Norte) is another important organization that has been carrying out interventions in the watershed for almost 20 years. Its projects incorporate both natural resource management and sustainable rural economic development and include activities such as pasture management, dairy farm management, strengthening of milk producers' organizations, and fruit tree nurseries.

There are many other organizations carrying out interventions in the watershed, including La Asociación para el Desarrollo Rural de Cajamarca (ASPADERUC); Compensación Equitativa por Servicios Ambientales Hidrológicos (CESAH), which is a consortium to establish mechanisms for payment of environmental services made up of CARE, the World Wildlife Fund (WWF), and the International Institute for Environment and Development (IIED); the Instituto de Cuencas; ITDG; and international organizations that partner with local NGOs to carry out interventions in the area, including DANIDA and GTZ.

PROJECT OBJECTIVES

The overall goal of this project is to increase agricultural productivity, incomes, and sustainable management of land and water by small farmers in the rural Sierra region of Peru. The project will pursue this goal by contributing to improved knowledge about the factors affecting the adoption of sustainable land and water management technologies and their impacts in the Jequetepeque watershed of northern Peru.

The specific objectives of this research in the Jequetepeque watershed are as follows:

1. Contribute to increased adoption of sustainable land and water management technologies by farmers in the Jequetepeque watershed
2. Improve knowledge among policy makers, technical assistance programs, farmers, researchers, and other stakeholders regarding best-fit sustainable land and water management options; key factors affecting adoption and their impacts and tradeoffs in the Jequetepeque watershed; and the prospects for adoption and impacts of these options in similar contexts elsewhere in the rural Sierra

OBJECTIVE 1: CONTRIBUTE TO INCREASED ADOPTION OF SUSTAINABLE LAND AND WATER MANAGEMENT TECHNOLOGIES BY FARMERS IN THE JEQUETEPEQUE WATERSHED

Methods

In order to determine high priority areas on which to focus, a typology of the Jequetepeque watershed was developed to closely examine the region, establish similarities and differences between areas, and allow for the scaling-up of results found in this study. The stochastic profit frontier approach used to develop this typology is based on a theory of producer behavior in which motivation is the usual optimization criteria (minimize costs or maximize profits), but in which success is not guaranteed. This approach allowed us to analyze the determinants of variation in the efficiency with which producers pursue their objectives. This method uses rich biophysical data from Peru and a highly detailed geo-referenced household survey of the region to estimate the efficiency of local farmers and rural workers given certain conditions such as climate, topology, prices, and their own economic and demographic characteristics. Using the stochastic profit frontier approach, a typology was constructed to estimate the profit efficiency for the Jequetepeque watershed. By estimating local efficiency levels and the factors influencing it, regional potentialities and bottlenecks were identified and used in the construction of the typology. This typology that was developed can be utilized by policymakers and other stakeholders to design pilot poverty reduction programs adapted to each micro-region's particular combination of development challenges. Three activities were used to accomplish this strategy:

- Gather biophysical data from Peru and a highly detailed geo-referenced household survey of the region to estimate the efficiency of local farmers and rural workers.
- Using the frontier estimation, predict the profit frontier and the inefficiency at the household level, from which regional level estimates can be extrapolated.
- Use this typology to highlight priority areas from which to select possible interventions to include in the study.

We then identified projects promoting soil, land, and water management technologies (SLWMT) and the land and water management technologies that are in use or have potential in the watershed, and assessed their potential impacts and tradeoffs, and the factors affecting adoption of SLWMT. The strategy was to improve knowledge of the best-fit SLWMT options for the JW watershed and similar environments elsewhere in the Sierra, based upon a review of and consultations with the projects promoting SLWMT, and assessment of the land and water management technologies being used or that could potentially be used in these environments. Five activities were used to accomplish this strategy:

- Make an inventory of recent, current and planned projects promoting SLWMT in JW, their locations, activities and farmers affected.
- Conduct a survey of households and collect soil samples in selected micro-watersheds of JW.
- Evaluate the impacts of the selected interventions using the household survey data collected.
- Conduct an institutional analysis in order to better understand farmers perceptions and successes and failures in selected intervention sites.
- Carry out a trade-off analysis in order to study adoption of SLWMT in the watershed.

The inventory of recent, current, and planned projects was used to identify interventions promoting SLWMT in JW, in order to study the potential and impacts of these in greater detail using a household survey and tradeoff analysis. This inventory was based upon information to be collected from the Coordinadora de la Cuenca Jequetepeque (CCJ) and the development projects and organizations working in the watershed, such as CEDEPAS Norte, GTZ, CARE, WWF, PRONAMACHCS, and others. The inventory sought information on the locations, activities (past, current and planned), beneficiaries and budget of these projects. It also sought information from the projects and organizations concerning how the intervention areas and target populations were identified, to assist in addressing selection issues in the subsequent evaluation of impacts of particular interventions.

The household survey and analysis assessed the determinants of adoption and impacts of SLWMT being used in JW, and the impacts of specific projects on these outcomes. Based on initial consultations with projects and organizations working in this watershed, and observations in the field, it appeared that adoption of most land and water management technologies was limited outside of areas of project intervention. Furthermore, quantitative information on the impacts of project interventions was identified as a critical knowledge gap by several project officials and other stakeholders in the watershed. Hence, the research team decided to focus the household survey on impacts of projects and other factors on adoption of SLWMT in areas of project intervention. To attribute differences in outcomes to the projects rather than to other factors , matching methods such as propensity score matching (Rosenbaum and Rubin 1983) and nearest neighbor matching (Abadie, et al. 2004) were used to assure that the comparisons between these groups are based on households that are as closely matched as possible in their pre-project characteristics. Data was collected on pre-project characteristics of the households that could jointly affect program participation and outcomes (e.g., education, endowments of land and major physical assets, access to markets and infrastructure). To assess the effects of other factors besides projects on adoption of SLWMT and their production and income impacts, multivariate econometric methods were also used. Analysis of the survey data, together with other available data, was used for ex post assessment of existing interventions.

Additionally, the household data collected was used to conduct an institutional analysis of the different actors in the Jequetepeque watershed. Building on the inventory of interventions in this area, one component of the household survey was geared towards generating a better understanding of the functioning of the different groups involved, social norms and enforcement and the role these play, and general dynamics. This data was then analyzed in order to examine issues of trust, entrepreneurship, organizational issues, and social norms and enforcement in each of the project intervention areas.

Using a bio-economic modeling approach that builds on earlier work in the Cajamarca province of Peru and other locations in the Andes (Antle, Stoorvogel and Valdivia 2007; Antle, et al. 2005; Stoorvogel, et al. 2004), we evaluated the adoption of promising interventions to promote SLWMT. The tradeoff analysis model assumes that farmers take land use and management decision to maximize their perceived economic well being. If farmers are provided with alternative technologies like soil and water conservation techniques they may switch practices if those technologies are economically viable. Farmers' management decisions influence erosion and water consumption in the watershed but typically the off farm effects are not considered in the decision making process. This model is used to evaluate the adoption of alternative practices in the Jequetepeque watershed.

Results

In order to select the interventions to be evaluated, we generated an inventory of all the projects that were being executed in the higher watershed region. Table 1 shows a list of these projects by institution; their main activities and the areas where they were being implemented, as well as the number of beneficiary families in each case. Most of these projects were administered by private NGOs, with the exception of PRONAMACHCS, a national program implemented by the Ministry of Agriculture. Most projects are relatively small, reaching a few hundred families, at most—a number that usually includes an estimated number of indirect beneficiaries. On the other hand, a majority of projects had a productive bias, and were concentrated in a few areas of the watershed.

Table 1. Inventory of current interventions in Upper Jequetepeque Watershed

Intervention Administrator	Main Activity	Number of Beneficiaries	Cajamarca				San Miguel			San Pablo				Contumazá			
			Magdalena	Chetila	San Juan	Asunción	El Prado	Aguablanca	San Miguel	San Pablo	San Luis	San Bernardino	Tumbaden	Contumazá	Chilete	Santa Cruz	Guzmango
CEDEPAS 1	Dairy production	120	■	■													
CEDEPAS 2	Training of organic extension agents	60	■				■	■									
CEDEPAS 3	Mango organic production	500					■	■									
CEDEPAS 4	Avocado plantations	80	■							■	■						
CEDEPAS 5	Avocado commercialization	485	■						■	■							
CEDEPAS 6	Soil conservation	100	■	■													
CEDEPAS + ITDG	Risk management	800	■				■	■		■		■		■	■		
ITDG	Local electricity generation	100								■			■				
GTZ + CEDEPAS	Watershed management		■						■	■				■	■		
CARE	Compensations for environmental services	332												■		■	■
ADEFOR	Reforestation and cattle management	1500											■				
PRONAMACHCS	Soil conservation and reforestation	700												■	■	■	■
ASPADERUC 1	Chirimoya crops	240	■		■	■											
ASPADERUC 2	Granadilla crops	120	■		■	■											
Instituto Cuencas	New herb varieties research	20		■													
GTZ	Territorial planning								■	■	■	■					
Regional Government	Various crop-oriented projects*		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

Source: Multiple interviews

*By the end of 2008, none of these projects was being executed yet.

Our review of the inventory of project interventions related to land and water management in the middle and upper Jequetepeque watershed was conducted, based upon available literature and project documents, and consultations with government and project officials and stakeholders in the watershed. This review identified 14 current projects managed by nongovernmental organizations (NGOs) and several programs of the regional and local governments (Table 1). Most of the government programs were just beginning in 2008 or 2009, and hadn't yet begun activities in the watershed at the time of this study. These interventions were presented to stakeholders in a workshop in Cajamarca during September, 2008. The stakeholders identified additional current interventions not included in the initial inventory, including projects managed by user committees in the watershed; development projects of the local district governments that may be related to land and water management; the PRONAMACHCS program; projects of the Regional Government of Cajamarca related to biodiversity, production of taya, and irrigation, and projects of the NGO ADEFOR related to forestry and production of taya. The stakeholders also identified several past development or research projects related to management of the watershed. They suggested several criteria to select interventions for study, including projects that:

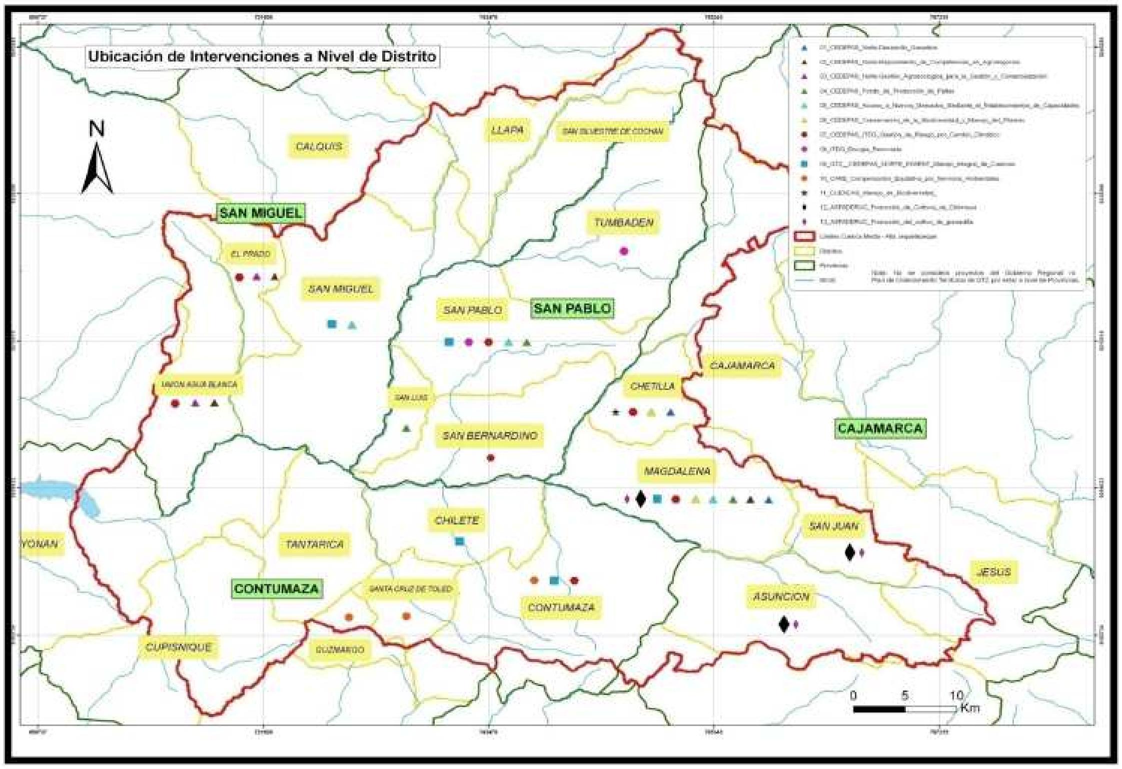
- improve the integrated management of the watershed;
- generate income for the farmers;
- improve the livelihoods of the people without forcing them to change their traditional activities (such as improving productivity of livestock production); and
- promote activities with greater productive potential in the watershed, taking into account factors such as the climate, erosion, etc.

Taking these criteria into account, as well as our own additional criteria – which included i) seeking to represent different parts of the watershed where different land uses and livelihood systems are dominant; ii) to assess ongoing projects that are likely to have had some impacts and land management and poverty already; and iii) to stay within the budget of our research project – we selected three projects and corresponding sites for the study:

- interventions of the PRONAMACHCS program promoting reforestation and soil and water conservation in Contumazá province;
- the CEDEPAS Norte project to promote livestock and pasture improvement in the districts of Chetilla and Magdalena in Cajamarca province; and
- the CEDEPAS Norte project to promote organic methods of fruit production and commercialization in the micro-watershed of the Payac River, in San Miguel province.

These interventions represent different parts of the mid to upper Jequetepeque watershed and different production systems having different land and water management problems and different levels of poverty. These include fruit production in the middle watershed (the CEDEPAS Norte project in the Payac micro-watershed), dairy production in moderately sloping areas of the northern upper watershed (the CEDEPAS Norte project in Chetilla and Magdelena districts), and cereal and potato production in steeply sloped areas of the southern upper watershed (PRONAMACHCS project in Contumazá province) (Map 1).

Map 1. Project interventions in the middle and upper Jequetepeque watershed



PRONAMACHCS reforestation and soil and water conservation program in Contumazá

PRONAMACHCS has been involved in the watershed since 1997, promoting reforestation and soil and water conservation measures. The program has worked in 18 communities in four districts of the Contumazá province: Contumazá, Guzmango, Santa Cruz de Toledo, and Tantarica. These communities are in the upper watershed, with most at median elevations above 2800 meters above sea level. These locations were presumably chosen by PRONAMACHCS because of the high levels or risk of land degradation and high poverty in the upper watershed. Most of these communities are relatively far (more than 30 km) from the provincial capital, and most lack access to basic infrastructure and services. Within each community, groups of participating farmers (socios) were formed to implement project activities. A little more than one fourth (27%) of the families in these communities participated as socios. The main activities promoted included establishment of tree nurseries and tree plantations, terraces and infiltration ditches. The level of involvement of PRONAMACHCS in these communities has declined in recent years as a result of declining budgets for the program.

CEDEPAS Norte livestock and pasture improvement project in Chetilla and Magdalena

CEDEPAS Norte has implemented a livestock and pasture improvement project in the districts of Chetilla and Magdalena focused on capacity building to improve incomes among the small producers of the area. From 1997 to 2008, there have been three phases of interventions designed to develop the productive and organizational capacities of the smallholder livestock producers in Chetilla and Magdalena. The first phase started in 1997 and continued through 2000. The project focused on increasing agricultural production via alternative crops and the promotion of organic methods, promoting efficient use of water for irrigation, intensification of livestock marketing and production, and forming small businesses. The second phase of the intervention took place from 2000 to 2003 and built upon the accomplishments of the first phase. In this phase, the intervention focused on capacity building for the previously formed cooperative organizations (CODEC y CODED). The goals of this phase included providing training in marketing and negotiations, improving product quality, optimizing water usage, systematizing experiences and lessons learned from the previous phase, and specializing professional capabilities. The third phase of the project focused on legal aspects and other improvements to the Association of Livestock

Producers, APROGAL. Gender was also an important focus in the third phase as CEDEPAS Norte worked to include women and promote more active participation in the livestock projects. In addition, this phase also put a much stronger emphasis on natural resource management through reforestation, construction of terraces, and incorporation of live fences on the smallholders' properties.

CEDEPAS Norte organic fruit production and commercialization project in Payac sub-watershed

The Payac microwatershed is located within the Jequetepeque watershed and can be found in the districts of Unión Agua Blanca and El Prado. There are approximately 6,000 people living within these two districts, and approximately 80% of these inhabitants live in rural areas. CEDEPAS Norte has been carrying out interventions related to mango production in this zone since 2000. The mango production intervention focuses on the middle and lower microwatershed, which totals approximately 500 hectares. The project began in 2000 when Sunshine Export was looking for new mango producers for exportation, and the microwatershed of Payac was identified as being a prime location for mango production. After providing some initial technical assistance and logistical support, CEDEPAS Norte began a more formal intervention in 2001 in order to coordinate both technical and administrative aspects of the production and marketing of mangos. The first intervention, carried out from 2001 to 2003, consisted of establishing a workplan, obtaining organic certification, and forming the producer's organization APEPAYAC. The second of CEDEPAS Norte's interventions, from 2004 to 2005, was directed at the technical aspects of production, including training in organic pest management practices, fertilizer, irrigation, and the packing and storage of mangos. The third intervention, carried out from 2006 to 2009, involved training local extensionists, introducing new crops, implementing practices to standardize the quality of mangos, and strengthening local organizations. They focus mainly on the Haden variety of mangos and have been producing approximately 4,000 tons per year. The project has reached a total of 812 beneficiaries throughout its 3 phases of interventions in the Payac microwatershed.

Selection of sample communities

Within each site, communities (centros poblados) benefiting from the project and matching non-project communities were selected to be as similar as possible in biophysical and socioeconomic characteristics that are relevant to land and water management and its outcomes. The purpose of this is to help control for confounding factors that differ between project and non-project communities that could influence differences in responses and outcomes. The variables used for this matching included the geological parent material of the soil, the soil type, altitude, slope, wetness index, land use, vegetation (measured by the normalized difference vegetation index (NDVI) using satellite data), the number of households in the community, and distance to the nearest town and to the nearest main road. These data were assembled in a geographic information system (GIS) by researchers from Wageningen University, and were drawn from secondary data sources, including data provided by CEDEPAS Norte (land use, soil type), IFPRI (geological material, distance to the nearest town and road), the population census (number of households), and data acquired or estimated by Wageningen University from other sources (altitude, slope, wetness index and NDVI). Exact matching was used for geological material, soil type and land use variables, combined with propensity score matching (nearest neighbor method) (Rosenbaum and Rubin 1983) on the other variables to select the best matches between communities with projects and those without. For example, of the 1065 communities (centros poblados) in the watershed, 66 communities were exact matches to all 8 CEDEPAS Norte project villages in Chetilla and Magdalena in terms of their parent geological material, soil type and land use (see Annex 1 for matching results of community selection).

Using nearest neighbor propensity score matching (PSM) with these 74 communities, 5 non-project villages were selected as the best matches to the 8 project villages based on data on mean elevation, slope, wetness index, NDVI, number of households, distance to the nearest town and distance to the nearest road. Similarly, 87 non-project villages were exact matches to 14 of the 16 PRONAMACHCS project villages in Contumazá in terms of geological material, soil type and land use. Of these 103 villages, 11 project villages and 9 non-project villages were selected as best matches using PSM. Matches having "common support" – i.e., being within the same range of values of the matching variables – could not be found for 3 of the project villages, so these villages were dropped. After the PSM, we dropped two of the 11 project villages, since they were matched to the same non-project village as another project village that was a better match than either of those two villages, resulting in 9 project villages and 9 matching nonproject villages in Contumazá.

For the CEDEPAS Norte project villages in the Payac River sub-watershed, 22 project villages and 214 non-project villages were selected as exact matches based on geological material and soil type. Of these, 17 project villages and 9 non-project villages were selected as the best matches using PSM with the remaining variables. After this matching, we dropped project villages that were outside of San Miguel province, where most of the Payac project villages were found (resulted in dropping 5 project villages), and the non-project villages that were matched to those project villages were dropped (4 villages dropped). Of the remaining 17 villages, we dropped project villages in which there were very few fruit producers, according to a list of fruit producers in the watershed compiled by the government agricultural phytosanitary agency SENASA and the

CEDEPAS Norte project beneficiary list, and the matching non-project villages (9 villages dropped).

The remaining 8 villages included 6 project villages and 2 matching non-project villages.

This selection resulted in a total of 39 communities in the sample, including 13 communities in Cajamarca province (Chetilla and Magdalena CEDEPAS Norte project site), including 8 project villages and 5 non-project villages; 18 communities in Contumazá (PRONAMACHCS program interventions), including 9 project villages and 9 non-project villages; and 8 communities in San Miguel province (CEDEPAS Norte Payac project site), including 6 project villages and 2 matching non-project villages. These tests show that the matched communities are much more similar in terms of these characteristics than the unmatched communities, with few statistically significant differences in mean values of these variables between the matched samples (significant differences only in the case of Payac), and in most cases smaller absolute differences in mean values. These results demonstrate the value of the matching procedure to select project and non-project communities that are similar in these characteristics, although there are still some differences.

Selection of sample households

The sample households were selected using a stratified random sample. Within each site, there existed up to four strata:

- Project beneficiaries who belonged to a producer organization formed by the intervention (beneficiaries who are "socios")
- Project beneficiaries who did not belong to a producer organization formed by the intervention ("no-socios")
- Project non-beneficiaries from the project villages

- Project non-beneficiaries from the non-project villages

For the first two strata, a random sample was drawn from lists of project beneficiaries provided by the project. Non-beneficiaries were sampled using slightly different approaches for the different project sites:

- For the PRONAMACHCS intervention in Contumazá province, 7 socios were selected from each project village. There were no no-socio beneficiaries. 7 non-beneficiary households were randomly selected in the non-project villages. Up to 7 non-beneficiary households were selected in project villages (all of these were selected if the total number of such households in project villages was less than or equal to 7, and 7 were randomly selected if the number was greater than 7).
- For the Payac project, all of the socios in the sample villages were included in the sample. No-socios were selected using proportional sampling by village (40% proportion of no-socios sampled) for the four villages with significant numbers of beneficiaries. For the two villages with only one beneficiary in each, the beneficiary was included in the sample. Households in the non-project villages were selected using 50% proportional sampling, sampling from a list of fruit producers compiled by SENASA, to insure that beneficiaries and non-beneficiaries in the sample were as comparable as possible. Non-beneficiary fruit producers in the project villages were identified during the conduct of the survey, and were sampled if found, up to the number of project beneficiaries in the same village.
- For the Chetilla project, all socios were included in the sample. Up to 8 no-socios were randomly selected per project village (if the total number of no-socios in a village was less

than or equal to 8, all were selected). Up to 8 non-beneficiary households in project villages were randomly selected (or all selected if no more than 8 such households in the village), and 8 households in non-project villages were randomly selected.

The resulting sample included 465 households across the three sites.

Data collection

The data were collected during December 2008 and January 2009 using structured questionnaires conducted separately with a man (usually the head of household) and a woman (usually the spouse of the head), if available. The female section of the questionnaire included questions on topic on which the female was more informed and the male sections in which he was more informed. Respondents participated voluntarily, after being informed about the objectives of the survey. The questionnaire for men included questions about the man's parents; the characteristics of the house; household assets; salary employment; non-agricultural employment; income from transfers, rental and sales of assets; remittances; characteristics of the land parcels owned or operated by the household; land uses on parcels and sub-parcels8; perceived land quality and land degradation on sub-parcels; land investments, land management practices and inputs used on subparcels; production of outputs on sub-parcels; production and disposition of crops by the household as a whole; production of agricultural sub-products (e.g. processed products); use of labor, inputs and agricultural equipment in crop production; investments in buildings and equipment; technical knowledge and participation in technical assistance programs; participation in specific projects (i.e., the CEDEPAS Norte projects in Chetilla or Payac, or the PRONAMACHCS program); access to and use of formal and informal credit; and use of and contributions to management of communal resources. The questionnaire for women included questions about the woman's parents; the composition and demography of the household; migration of household members; education of household members; household consumption expenditures; access to community services and infrastructure; production of livestock and livestock products; use of labor and other inputs in livestock production; forestry and other livelihood activities; and technical knowledge and access to technical assistance for women.

Questions related to income referred to the 12 months prior to the survey (i.e., the calendar year 2008), while questions related to household consumption referred to the month prior to the survey. Questions about household composition and assets referred to the time of the survey and the beginning of 2006, so that asset levels prior to implementation of the recent projects being assessed (in the case of the two CEDEPAS Norte projects) could be used in the analysis. This also allowed assessment of changes in assets between the beginning of 2006 and the end of 2008.
In addition to administering the questionnaires, the enumerators visited each household's most important land parcel and measured its geographic coordinates, altitude, and area.

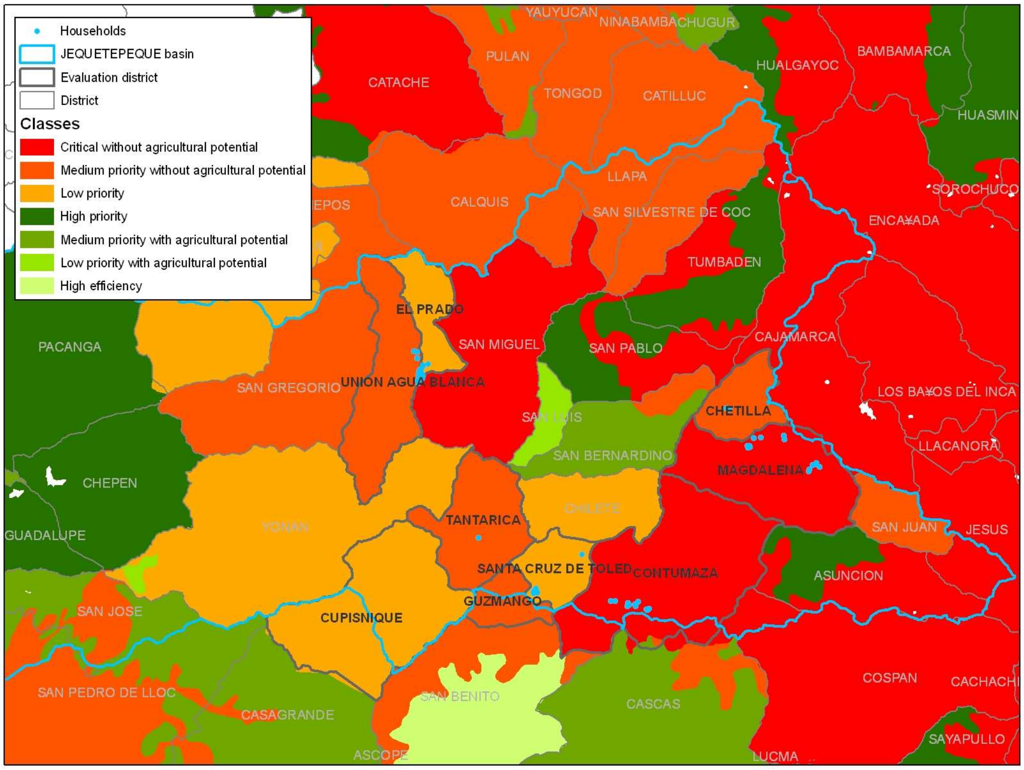
Results

Typology results

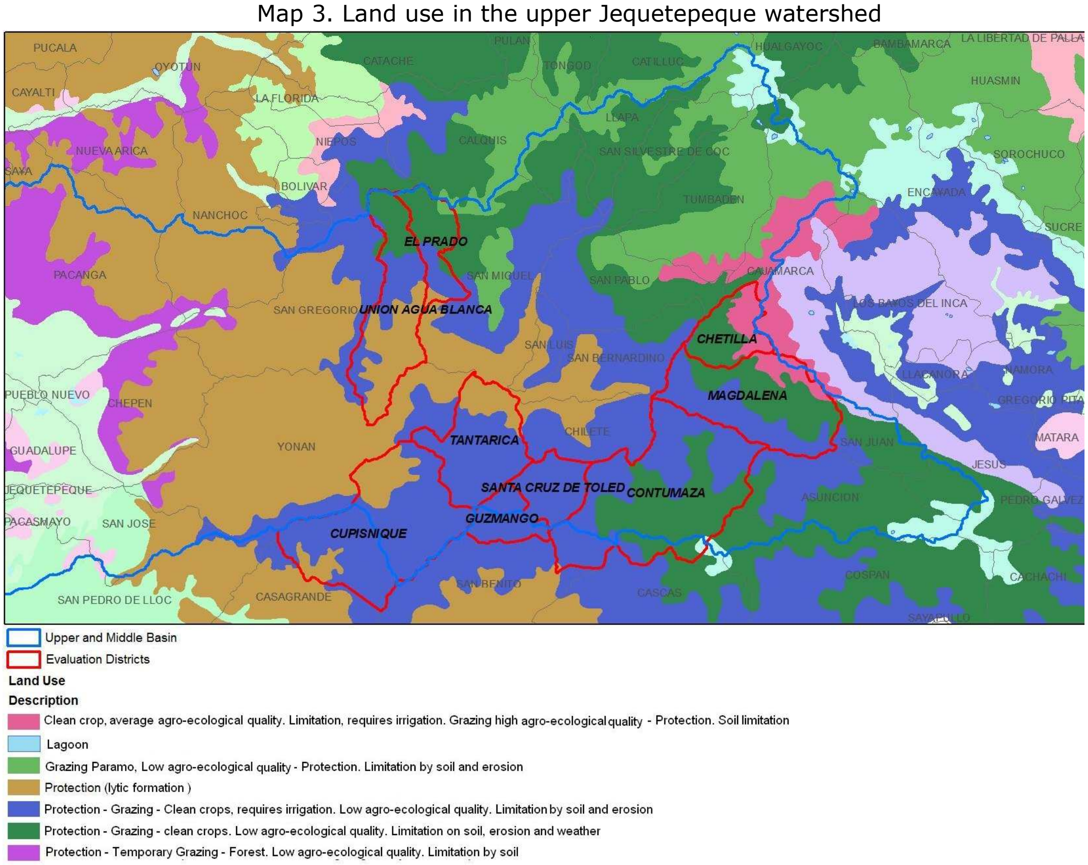
The frontier estimation allows us to predict both agricultural potential and inefficiency at the household level, from which we can extrapolate regional level estimates. In addition, conducting a simple regression analysis allows us to estimate the determinants of this inefficiency. From this regression, we observe that higher agricultural potential is associated with higher efficiency. The analysis also shows that a solid grasp of the Spanish language is associated with higher efficiency. In addition, there is a positive association between household size and efficiency, indicating the probable existence of labor market failures which lead to technical inefficiency. Access to the formal credit market and ownership of one's parcel generate higher efficiency for those households with greater agricultural potential. Finally, accessibility costs reduce efficiency.

The typology designed for the rural Sierra is based on criteria such as poverty levels, production capacity, efficiency in natural resource management, market conditions, and agroecological conditions in each zone. The following map (Map 2) depicts these microregions that were defined by the analysis of the upper Jequetepeque watershed. The map depicts the zones with little agricultural potential in red shades, while the green shades indicates zones with medium to high agricultural potential. On both the red and green scales, the darker shades indicate higher poverty levels. According to the typology, the districts chosen for the study are zones of low agricultural potential and high poverty levels. The low potential is consistent with the soil quality (they're mostly located in protected parts of the watershed) and steep inclines. These are zones of high elevation with scarce water resources. Approximately 69% of the land in the upper Jequetepeque watershed is protected, 23% is used for grazing, and only 8% is dedicated to agricultural activity. See Map 3 for more information on land use in the watershed. The zone of analysis has medium to high levels of accessibility, which can be seen in Map 4.

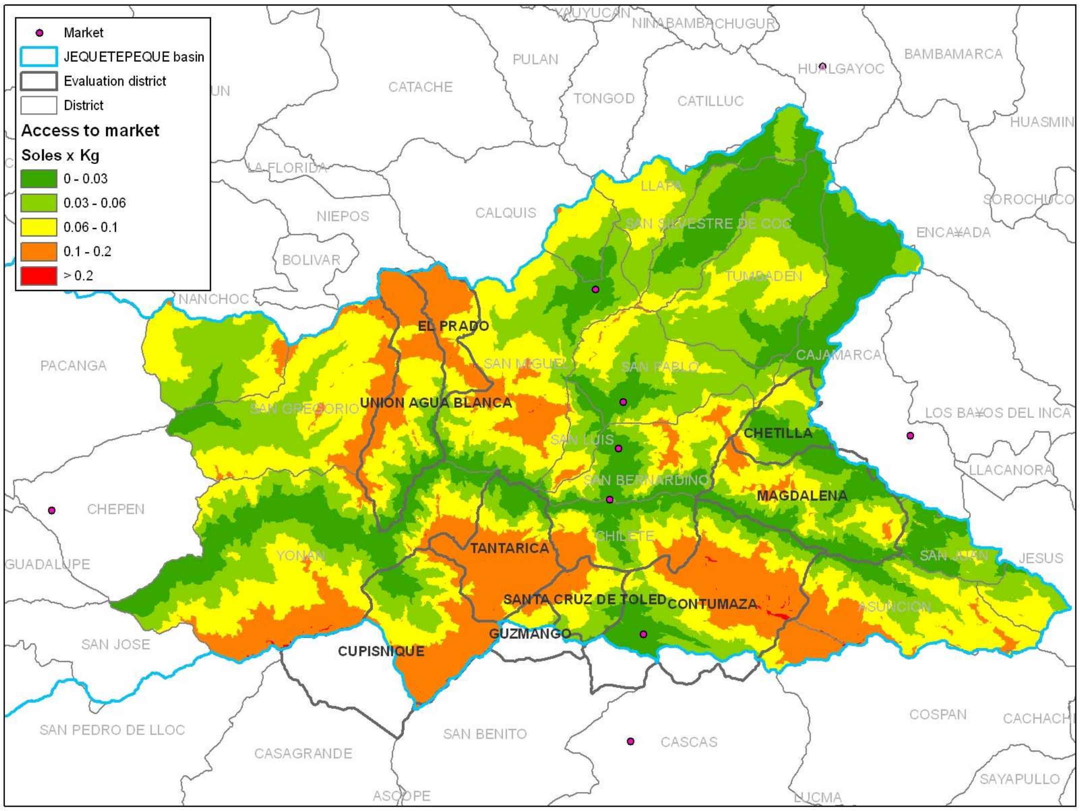
Map 2. Microregions in the upper Jequetepeque watershed



Map 3. Land use in the upper Jequetepeque watershed



Map 4. Accessibility to markets in the upper Jequetepeque watershed



Impact analysis results

The data were analyzed using i) simple comparisons of means of response (land use, land investments and land management practices) and outcome variables (crop yields, perceived land degradation, income, change in assets) between project beneficiaries and non-beneficiaries; and ii) comparisons of mean responses and outcomes between beneficiaries and non-beneficiaries using propensity score matching (PSM) (Rosenbaum and Rubin 1983) and nearest neighbor matching (NN) (Abadie, et al 2004). These matching methods were used to control for the effects of confounding factors that influence land management responses and outcomes and may be correlated with project participation. Although the method used to select matching project and non-project villages for this study helps to control for such factors, this method only controlled for differences in community level variables that were available from secondary sources prior to the survey. In the matching analysis conducted after the survey, differences in household and parcel level confounding variables were also accounted for – including the age, gender and education of the household head; the share of dependents and female share of nondependents in the household; the area of land owned and share titled; the value of livestock, farm equipment and durable assets owned; and the altitude, slope and size of the parcel.

We used both PSM and nearest neighborhood (NN) matching methods to evaluate the robustness of our findings because each method has advantages and disadvantages. PSM has the advantage that the propensity score, which is estimated using a probit model (or other probability model) to estimate the probability (or "propensity") that a household will participate in the project, implicitly gives greater weight to covariates that have a larger impact on project participation. This is advantageous since only factors that are correlated with participation can cause a selection bias. The NN method uses a more arbitrary metric to weigh the influence of different covariates on the distance metric.9 However, PSM may be biased because of imperfect matching. Furthermore, the standard errors computed by the PSM procedure are incorrect, because they do not account for the fact that the propensity scores are based on estimated values of incorrect standard errors for the case of nearest neighbor PSM (Abadie and Imbens 2006). We used kernel matching (using the default Epanechnikov kernel) rather than nearest neighbor matching (which is more efficient than nearest neighbor PSM), but there is no assurance that the standard errors estimated by bootstrapping are correct. To account for possible non-independence of observations of different parcels and sub-parcels from the same household, we used the Stata cluster option with the bootstrap procedure, clustering observations by household.

The NN method addresses the problem of bias by estimating a bias corrected estimator, based on auxiliary regressions to account for the impacts of bias. This is advantageous, but it reduces the advantage of using matching procedures relative to more parametric regression procedures, since the results will depend upon the validity of the parametric assumptions underlying the auxiliary regressions. Unlike the PSM estimator, the standard errors estimated by the NN procedure are analytically correct (for independent observations), since there is no two stage procedure involved in the estimation. However, the NN procedure does not allow for a clustering option, so the standard errors could be incorrect due to non-independence of observations, such as may be the case for multiple parcel level observations from the same household.

Thus both matching methods have advantages and drawbacks relative to each other. By using both methods we can investigate the extent to which empirical findings depend on the matching method, thus providing a test of the robustness of the conclusions. However, this does not rule out possible bias due to "selection on unobservables" (Heckman, et al. 1998). Even if the matching were perfect on all covariates, there still could be unobserved factors that differ between project beneficiaries and nonbeneficiaries that account for differences in the responses and outcomes of these two groups. The validity of the results of any type of matching estimator depends upon the assumption of conditional independence; i.e., the assumption that the outcome that would occur without the program is independent of whether or not the household is in the program, conditional on observed characteristics of households (Rosenbaum and Rubin 1983). Unfortunately, this assumption is not testable. It is like the untestable assumption in ordinary least squares regression models that the expected value of the error term, conditional on the covariates, is zero. Thus matching estimators suffer from some of the same potential biases as ordinary least squares regression. However, matching estimators are less affected by parametric assumptions than regression models, and reduce biases that could be caused by comparing non-comparable observations when matching is done using observations that have "common support" (as we have done in this analysis) (Heckman, et al. 1998). For these reasons we prefer the use of matching estimators over ordinary regression models to estimate the impacts of projects, even if these estimators are still imperfect.

Characteristics, Responses and Outcomes of Project Beneficiaries and Non-Beneficiaries

In this section we discuss the characteristics of beneficiaries and non-beneficiaries in the three selected project interventions in the Jequetepeque watershed, and the similarities and differences in land use and land management decisions, agricultural productivity, land degradation and welfare indicators between these groups.

Selected characteristics of project beneficiaries and non-beneficiaries and of the parcels that they manage are presented in Table 2. Across the three project sites, households in Contumazá are the poorest on average in terms of assets, owning less land and durable household assets than households in the other two sites, and with a smaller share of their land titled. Households in Chetilla own the most land and livestock, but own much less durable household assets than those in Payac. Household heads in Chetilla are less educated than those in the other two sites. Household heads in Payac are older and more educated, and Payac households are smaller, have a smaller share of dependents, and are more likely to be female headed than those in the other two sites. Households in Chetilla are located at the highest elevation of the three sites, and are furthest from a main road, while those in Payac are at the lowest elevation and closest to a main road. However, Payac households are further from the nearest town than those in the other two sites. Land parcels are most likely to be on flat land in Payac and most likely to be on steep land in Contumazá. Parcel sizes are larger in Chetilla than in either of the other two sites, reflecting more extensive use of land for pastures in this site.

Table 2. Characteristics of project beneficiary vs. non-beneficiary households and their parcels (standard errors in parentheses)

Variable	Chetilla		Contumazá		Payac	
	Ben.	Non-ben.	Ben.	Non-ben.	Ben.	Non-ben.
Household level variables						
Number of observations	49	118	62	97	69	65
Household size in 2008	5.22 (0.26)	4.93 (0.17)	4.95 (0.23)	4.45 (0.21)	3.33 (0.21)	3.78 (0.21)
Household size in 2006	5.10 (0.26)	4.74 (0.17)	4.76 (0.22)	4.38 (0.21)	3.29 (0.21)	3.85 (0.21)
Age of household head (years)	43.2 (2.1)	45.2 (1.3)	44.5 (1.7)	46.3 (1.5)	52.7 (1.6)	50.9 (1.8)
Schooling of household head (years)	3.67 (0.40)	3.22 (0.30)	5.67 (0.36)	5.40 (0.31)	6.06 (0.50)	6.00 (0.51)
Share of dependents	0.465 (0.026)	0.444 (0.019)	0.426 (0.026)	0.428 (0.027)	0.298 (0.033)	0.374 (0.036)
Female head	0.041* (0.029)	0.110* (0.029)	0.062 (0.025)	0.016 (0.016)	0.145 (0.043)	0.169 (0.047)
Female share of non-dependents	0.553 (0.024)	0.550 (0.020)	0.509 (0.021)	0.501 (0.021)	0.516 (0.034)	0.541 (0.036)
Land area owned in 2008 (ha)	5.61 (2.27)	7.72 (3.86)	1.27 (0.16)	1.72 (0.25)	2.15* (0.27)	1.52* (0.19)
Share of land titled	0.350 (0.068)	0.311 (0.042)	0.234 (0.054)	0.192 (0.039)	0.577 (0.059)	0.566 (0.060)
Value of livestock in 2008 (S/.)	7013.0** (1357.1)	3723.4** (415.2)	2912.2* (370.5)	4875.9* (1116.1)	999.0 (134.8)	869.3 (242.9)
Value of livestock in 2006 (S/.)	7243.2*** (1606.8)	2610.1*** (311.0)	2848.2 (428.6)	3837.4 (513.6)	786.1 (143.1)	539.4 (110.6)
Value of farm equipment in 2008 (S/.)	166.9 (44.1)	110.5 (11.8)	127.3 (13.7)	128.3 (10.5)	524.4 (352.6)	141.6 (22.0)
Value of farm equipment in 2006 (S/.)	176.1** (29.6)	109.6** (9.7)	132.1 (12.6)	127.9 (8.6)	588.6 (355.3)	120.1 (15.9)
Value of household durable assets in 2008 (S/.)	10520.2* (2015.5)	6361.8* (955.0)	4663.6 (1141.7)	4712.2 (1013.2)	23783.6*** (3264.0)	8080.7*** (1250.3)
Value of household durable assets in 2006 (S/.)	9138.7* (1991.8)	5392.4* (870.3)	4216.8 (990.1)	4443.8 (936.5)	18202.5*** (2761.4)	6913.8*** (1235.3)
Distance to the nearest town (km)	4.390 (0.313)	4.961 (0.297)	4.682 (0.313)	4.080 (0.207)	19.150 (0.183)	19.233 (0.175)
Distance to the nearest main road (km)	8.076** (0.192)	7.477** (0.135)	5.596 (0.398)	5.695 (0.382)	0.816*** (0.054)	0.593*** (0.057)
Altitude of the main parcel (meters above sea level)	3308** (38)	3208** (25)	2834 (74)	2689 (48)	991** (24)	1068** (27)
Parcel level variables						
Number of observations	85	175	92	166	123	117
Slope – flat	0.165 (0.040)	0.211 (0.031)	0.141 (0.037)	0.139 (0.027)	0.350 (0.043)	0.350 (0.044)
Slope – moderate	0.588 (0.054)	0.531 (0.038)	0.565 (0.052)	0.518 (0.039)	0.350 (0.043)	0.419 (0.046)
Slope – steep	0.106 (0.034)	0.154 (0.027)	0.250 (0.045)	0.289 (0.035)	0.154 (0.033)	0.128 (0.031)
Slope – mixed	0.141 (0.038)	0.103 (0.023)	0.043 (0.021)	0.054 (0.018)	0.146 (0.032)	0.103 (0.028)

*, **, *** mean difference between beneficiaries and non-beneficiaries in the site is statistically significant at 10%, 5% and 1% level, respectively

Within each site, there are some differences between beneficiaries and non-beneficiaries, despite the fact that beneficiary and non-beneficiary communities were selected to be similar in biophysical and socioeconomic characteristics. In Chetilla, beneficiary households in the CEDEPAS Norte project are less likely to be female headed, own significantly more livestock, farm equipment and household assets, are at a higher elevation and further from a main road than non-beneficiaries.12

Many of these differences reflect the fact that the CEDEPAS Norte project in Chetilla is focused on promoting improved livestock production; hence it is not too surprising that the beneficiaries own more livestock or are at higher elevation and further from a road. Female headed households may be less likely to focus on livestock production, resulting in lower representation of these households among beneficiaries. In Contumazá, sample PRONAMACHCS program beneficiaries are similar to non-beneficiaries in most respects, except that beneficiaries own less livestock. In Payac, CEDAPAS Norte project beneficiaries own more land and household assets than non-beneficiaries, have larger parcels, are at lower elevations and further from the nearest main road.

The greater assets owned by project beneficiaries in Chetilla and Payac are not necessarily due to impacts of the CEDEPAS projects in these sites, since these project beneficiaries already had more assets at the beginning of 2006, prior to the beginning of the recent projects in these sites. It could be that earlier interventions by CEDEPAS Norte in these sites contributed to greater assets of the beneficiaries who participated in earlier projects (such as the members of APROGAL in Chetilla and APEPAYAC in Payac). We are not able to investigate these earlier impacts, due to lack of data on assets owned by these households prior to 2006. Below, we do investigate whether there have been differences in asset accumulation since 2006 between beneficiaries and non-beneficiaries, which could reflect the impacts of the most recent projects.

Given observed differences in characteristics of project beneficiaries and non-beneficiaries in the study sites, simple comparisons between land management responses and outcomes of beneficiaries vs. nonbeneficiaries could be affected by these different characteristics. Hence, although we present such simple comparisons in the rest of this section, we reserve judgments about project impacts until the following section, in which we construct comparisons between matched groups of beneficiaries and non-beneficiaries having similar characteristics.

Land use and land management responses of beneficiaries and non-beneficiaries

Land uses and recent (since 2006) land use changes by project beneficiaries and non-beneficiaries are presented in Table 3. The most common land use found in the Chetilla and Contumazá sites is annual crop production, while perennial crops are most common in the Payac site. Pastures are also a common land use in Chetilla, while annual crops are fairly common in Payac. Most parcels did not have any land use change between 2006 and 2008. In Chetilla, the most common land use change was from pasture to annual crop production and vice versa. Of parcels that were used for pasture in 2006 by non-beneficiaries in Chetilla, nearly 49% were used for annual crops in 2008; while only 22% of beneficiaries' 2006 pasture parcels were used for annual crops in 2008. This large and statistically significant difference in conversion of pastures to annual crops suggests that the CEDEPAS Norte livestock and pasture improvement project helped to reduce such conversions. We will discuss this relationship further in section 5 based on matched comparisons.
In Contumazá, a smaller proportion of PRONAMACHCS beneficiaries' parcels with perennial crops in 2006 were used for pasture in 2008, though the number of parcels with perennials was quite small for both groups. Conversely, pasture parcels (also rare in Contumazá) were less likely to be shifted to perennial crops by PRONAMACHCS beneficiaries. These beneficiaries were also less likely to make improvements to their pastures than non-beneficiaries. These results suggest that PRONAMACHCS beneficiaries have a smaller tendency to invest in land use change or pasture improvement than nonbeneficiaries. This could be related to the fact that PRONAMACHCS beneficiaries have less livestock, as noted above. In Payac, we find no statistically significant differences in recent land use changes between project beneficiaries and non-beneficiaries. For both groups, some parcels with annual crops in 2006 began to be used for perennial crops by 2008, while a few perennial crop parcels were converted to annual crops. Very few parcels with other land uses are found in the Payac sample.

Table 3. Land use changes by project beneficiaries vs. non-beneficiaries
Proportion of parcels (standard errors in parentheses)

Variable	**Chetilla**		**Contumazá**		**Payac**	
	Ben.	Non-ben.	Ben.	Non-ben.	Ben.	Non-ben.
Number of parcels with annual crops in 2006	51	136	81	119	30	24
Annual crops in 2008 | Annuals in 2006	0.863 (0.049)	0.838 (0.032)	0.938 (0.027)	0.916 (0.026)	0.833 (0.078)	0.967 (0.033)
Perennial crops in 2008 | Annuals in 2006	0.020 (0.020)	0.022 (0.013)	0.012 (0.012)	0.017 (0.012)	0.133 (0.063)	0.292 (0.095)
Pasture in 2008 | Annuals in 2006	0.098 (0.042)	0.184 (0.033)	0.074 (0.029)	0.050 (0.020)	0.000 (0.000)	0.000 (0.000)
Fallow in 2008 | Annuals in 2006	0.039 (0.027)	0.088 (0.024)	0.062 (0.027)	0.050 (0.020)	0.033 (0.033)	0.042 (0.042)
Number of parcels with perennial crops in 2006	4	4	4	14	88	85
Perennial crops in 2008 | Perennials in 2006	0.500 (0.289)	1.000 (0.000)	1.000 (0.000)	0.929 (0.071)	0.932 (0.027)	0.965 (0.020)

Annual crops in 2008 | Perennials in 2006	0.500 (0.289)	0.000 (0.000)	0.000 (0.000)	0.143 (0.097)	0.068 (0.027)	0.071 (0.028)
Pasture in 2008 | Perennials in 2006	0.000 (0.000)	0.000 (0.000)	0.000* (0.000)	0.214* (0.114)	0.000 (0.000)	0.000 (0.000)
Fallow in 2008 | Perennials in 2006	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.012 (0.012)
Number of parcels with pastures in 2006	23	41	8	14	0	1
Pasture in 2008 | Pasture in 2006	0.696 (0.098)	0.756 (0.068)	1.000** (0.000)	0.714*** (0.125)	NE	NE
Annual crops in 2008 | Pasture in 2006	0.217** (0.088)	0.488** (0.079)	0.750 (0.164)	0.571 (0.137)	NE	NE
Perennial crops in 2008 | Pasture in 2006	0.043 (0.024)	0.024 (0.024)	0.000* (0.000)	0.214* (0.114)	NE	NE
Fallow in 2008 | Pasture in 2006	0.043 (0.043)	0.049 (0.034)	0.000 (0.000)	0.000 (0.000)	NE	NE
Number of sub-parcels with natural pastures in 2006	29	73	17	23	0	1
Improved pasture in 2008 | Natural pasture in 2006	0.172 (0.071)	0.096 (0.035)	0.000** (0.000)	0.174** (0.081)	NE	NE

*, **, *** mean difference between beneficiaries and non-beneficiaries in the site is statistically significant at 10%, 5% and 1% level, respectively
NE: not estimated due to zero or small number of observations

The most common land investments in the study sites include tree planting, construction of terraces or infiltration ditches, and other investments, most of which are related to irrigation (Table 4). Tree planting has been most common in Chetilla and Contumazá (occurring on more than 20% of parcels since 1998). Terrace construction was most common in Contumazá, followed by Chetilla. Construction of infiltration ditches was most common among project beneficiaries in Chetilla and Contumazá. Other investments were most common in Payac. In Chetilla, the only statistically significant difference between investments by project beneficiaries and non-beneficiaries was in constructing infiltration ditches, which was more commonly done by project beneficiaries than non-beneficiaries since 1998. Since we find little of such investments since 2006 and no significant difference between beneficiaries and non-beneficiaries in their likelihood of making recent investments, this difference does not appear to be due to the current CEDEPAS Norte project in Chetilla, though it could have been influenced by earlier interventions by CEDEPAS Norte. In Contumazá, the likelihood of investing in terraces, tree planting and infiltration ditches since 1998 is substantially greater for PRONAMACHCS beneficiaries than non-beneficiaries.

As in Chetilla, these investments are much less common since 2006, and the differences between beneficiaries and nonbeneficiaries in the probability of investing since 2006 are not statistically significant. Hence it appears that PRONAMACHCS has affected these land investments, but mainly before 2006. In Payac we find no statistically significant differences between beneficiaries and non-beneficiaries in their likelihood of making land investments. The most common investments have been tree planting and other (mostly irrigation) investments, occurring on between 10% and 14% of parcels since 1998.

Table 4. Land investments of project beneficiaries vs. non-beneficiaries
Proportion of parcels (standard errors in parentheses)

Variable	**Chetilla**		**Contumazá**		**Payac**	
	Ben.	Non-ben.	Ben.	Non-ben.	Ben.	Non-ben.
Number of observations	85	175	92	166	123	117
Terrace constructed since 2006	0.024 (0.017)	0.034 (0.014)	0.087 (0.030)	0.054 (0.018)	0.008 (0.008)	0.009 (0.009)
Infiltration ditch constructed since 2006	0.012 (0.012)	0.000 (0.000)	0.022 (0.015)	0.000 (0.000)	0.016 (0.011)	0.034 (0.017)
Trees Planted since 2006	0.106 (0.034)	0.063 (0.018)	0.098 (0.031)	0.048 (0.017)	0.024 (0.014)	0.017 (0.012)
Other investment since 2006	0.012 (0.012)	0.029 (0.013)	0.011 (0.011)	0.024 (0.012)	0.089 (0.026)	0.085 (0.026)
Terrace constructed since 1998	0.176 (0.042)	0.194 (0.030)	0.424*** (0.052)	0.205*** (0.031)	0.033 (0.016)	0.043 (0.019)
Infiltration ditch constructed since 1998	0.153* (0.039)	0.074* (0.020)	0.098** (0.031)	0.018** (0.010)	0.049 (0.020)	0.034 (0.017)
Trees Planted since 1998	0.424 (0.054)	0.326 (0.036)	0.402*** (0.051)	0.205*** (0.031)	0.106 (0.028)	0.137 (0.032)
Other investment since 1998	0.094 (0.032)	0.046 (0.016)	0.065 (0.026)	0.066 (0.019)	0.106 (0.028)	0.111 (0.029)

*, **, *** mean difference between beneficiaries and non-beneficiaries is statistically significant at 10%, 5% and 1% level, respectively

The most common crops grown in the study sites include cereals such as wheat, barley, maize and rice; legumes such as peas and beans; root crops such as potatoes, oca and olluco; and fruits such as mango, maracuya and avocado (Table 5). The crops grown differ greatly across the sites, with potatoes and barley most common in Chetilla; wheat, maize and potatoes most common in Contumazá; and fruits and maize most common in Payac. In Chetilla, project beneficiaries are significantly less likely than non-beneficiaries to grow wheat in the rainy season, peas in either season, or maize in the dry season. In Contumazá, we find no statistically significant differences in crop choices between project beneficiaries and non-beneficiaries. In Payac, project beneficiaries are more likely than non-beneficiaries to grow rice in either season, and are more likely to grow mangos.

Table 5. Crop choice in 2008 of beneficiaries vs. non-beneficiaries
Proportion of sub-parcels (standard errors in parentheses)

Variable	**Chetilla**		**Contumazá**		**Payac**	
	Ben.	Non-ben.	Ben.	Non-ben.	Ben.	Non-ben.

Variable	Chetilla		Contumazá		Payac	
	Ben.	Non-ben.	Ben.	Non-ben.	Ben.	Non-ben.
Rainy season						
Number of observations	82	195	97	161	116	109
Wheat	0.073*** (0.029)	0.185*** (0.028)	0.495 (0.051)	0.553 (0.039)	0.000 (0.000)	0.000 (0.000)
Barley	0.341 (0.053)	0.308 (0.033)	0.124 (0.034)	0.137 (0.027)	0.000 (0.000)	0.000 (0.000)
Peas	0.098*** (0.033)	0.221*** (0.030)	0.175 (0.039)	0.199 (0.032)	0.000 (0.000)	0.000 (0.000)
Beans	0.000 (0.000)	0.005 (0.005)	0.072 (0.026)	0.081 (0.022)	0.086 (0.026)	0.147 (0.034)
Maize	0.061 (0.027)	0.092 (0.021)	0.320 (0.048)	0.323 (0.037)	0.189 (0.037)	0.220 (0.040)
Rice	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.103** (0.028)	0.028** (0.016)
Potatoes	0.524 (0.055)	0.492 (0.036)	0.268 (0.045)	0.205 (0.032)	0.000 (0.000)	0.000 (0.000)
Oca	0.159 (0.041)	0.138 (0.025)	0.010 (0.010)	0.006 (0.006)	0.000 (0.000)	0.000 (0.000)
Olluco	0.085 (0.031)	0.123 (0.024)	0.031 (0.018)	0.012 (0.009)	0.000 (0.000)	0.000 (0.000)
Mango	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.793* (0.038)	0.679* (0.045)
Maracuya	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.095 (0.027)	0.046 (0.020)
Avocado	0.000 (0.000)	0.000 (0.000)	0.0103 (0.0103)	0.000 (0.000)	0.172 (0.035)	0.257 (0.042)
Dry season						
Number of observations	59	111	91	132	97	100
Wheat	0.017 (0.017)	0.036 (0.018)	0.154 (0.038)	0.167 (0.033)	0.000 (0.000)	0.000 (0.000)
Barley	0.119 (0.042)	0.081 (0.026)	0.011 (0.011)	0.008 (0.008)	0.000 (0.000)	0.000 (0.000)
Peas	0.000* (0.000)	0.027* (0.015)	0.011 (0.011)	0.023 (0.013)	0.000 (0.000)	0.000 (0.000)
Beans	0.000 (0.000)	0.000 (0.000)	0.033 (0.019)	0.045 (0.018)	0.031 (0.018)	0.080 (0.027)
Maize	0.000** (0.000)	0.054** (0.022)	0.154 (0.038)	0.189 (0.034)	0.113 (0.032)	0.130 (0.034)
Rice	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.082** (0.028)	0.020** (0.014)
Potatoes	0.186 (0.051)	0.144 (0.033)	0.264 (0.046)	0.197 (0.035)	0.000 (0.000)	0.000 (0.000)
Oca	0.051 (0.029)	0.036 (0.018)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Olluco	0.017 (0.017)	0.018 (0.013)	0.000 (0.000)	0.008 (0.008)	0.000 (0.000)	0.000 (0.000)

*, **, *** mean difference between beneficiaries and non-beneficiaries is statistically significant at 10%, 5% and 1% level, respectively

The most common annual or seasonal land management practices used in the study sites includes manuring, crop rotation, burning, contour planting, contour plowing, incorporating crop residues, minimum till, no till, compost, and green manures (Table 6). Use of mulch or cover crops also occurs, but these practices are fairly rare (less than 5% of parcels in all sites). Use of these practices differs across the sites and between seasons. For example, manuring, crop rotation and incorporation of green manures are more common in the annual based cropping systems of Chetilla and Contumazá than in Payac, while no till and compost use are more common in the perennial systems of Payac (especially among project beneficiaries in Payac). Burning is more common in the dry season (probably because there is more vegetation to manage after the rainy season, and because it is easier to burn in the dry season), while manure and compost are more commonly used in the rainy season. There are also significant differences between beneficiaries and non-beneficiaries in their use of these practices within each study site. In Chetilla, beneficiaries are more likely than non-beneficiaries to use compost in the rainy season and manure in the dry season (possibly related to their greater ownership of livestock), and green manures or cover crops in either season. In Contumazá, beneficiaries are less likely to use crop rotation in the rainy season, contour planting or contour plowing in either season, or no till in the rainy season, but are more likely to incorporate crop residues in the rainy season and to use a cover crop in the dry season. In Payac, beneficiaries are more likely to use compost in either season and to use no till, manure or mulch in the rainy season; but less likely to use contour planting in the dry season.

Table 6. Land management practices in 2008 of beneficiaries vs. non-beneficiaries
Proportion of sub-parcels (standard errors in parentheses)

Variable	**Chetilla**		**Contumazá**		**Payac**	
	Ben.	Non-ben.	Ben.	Non-ben.	Ben.	Non-ben.
Rainy season 2008						
Number of observations	82	168	89	156	113	109
Burning	0.073 (0.029)	0.042 (0.015)	0.090 (0.030)	0.096 (0.024)	0.099 (0.028)	0.110 (0.030)
Crop rotation	0.488 (0.056)	0.476 (0.039)	0.393*** (0.052)	0.615*** (0.039)	0.186 (0.037)	0.183 (0.037)
Contour planting	0.232 (0.047)	0.214 (0.032)	0.236* (0.045)	0.340* (0.038)	0.257 (0.041)	0.266 (0.043)
Contour plowing	0.110 (0.035)	0.179 (0.030)	0.258** (0.047)	0.378** (0.039)	0.259 (0.042)	0.174 (0.037)
No till	0.024 (0.017)	0.042 (0.015)	0.022 (0.016)	0.051 (0.018)	0.230* (0.040)	0.138* (0.033)
Minimum till	0.232 (0.047)	0.268 (0.034)	0.191 (0.042)	0.244 (0.034)	0.142 (0.033)	0.119 (0.031)
Manure	0.585 (0.055)	0.560 (0.038)	0.539 (0.053)	0.474 (0.040)	0.398* (0.046)	0.275* (0.043)
Compost	0.073** (0.029)	0.012** (0.008)	0.011 (0.011)	0.006 (0.006)	0.195*** (0.037)	0.028*** (0.016)
Mulch	0.024 (0.017)	0.012 (0.008)	0.022 (0.016)	0.019 (0.011)	0.027* (0.015)	0.000* (0.000)
Incorporate crop residues	0.195 (0.044)	0.143 (0.027)	0.404*** (0.052)	0.237*** (0.034)	0.239 (0.040)	0.266 (0.043)
Green manure	0.159** (0.041)	0.060** (0.018)	0.191 (0.042)	0.231 (0.034)	0.018 (0.012)	0.009 (0.009)
Cover crop	0.049** (0.024)	0.000** (0.000)	0.045 (0.022)	0.013 (0.009)	0.035 (0.017)	0.018 (0.013)
Dry season 2008						
Number of observations	68	119	81	141	108	106
Burning	0.103 (0.037)	0.118 (0.030)	0.198 (0.045)	0.206 (0.034)	0.287 (0.044)	0.387 (0.048)
Crop rotation	0.221 (0.051)	0.193 (0.036)	0.296 (0.051)	0.390 (0.041)	0.093 (0.028)	0.085 (0.027)
Contour planting	0.044 (0.025)	0.092 (0.027)	0.074*** (0.029)	0.291*** (0.038)	0.120*** (0.031)	0.264*** (0.043)
Contour plowing	0.059 (0.029)	0.092 (0.027)	0.099*** (0.033)	0.305*** (0.039)	0.121 (0.032)	0.170 (0.037)
No till	0.029 (0.021)	0.017 (0.012)	0.000*** (0.000)	0.050*** (0.018)	0.157 (0.035)	0.151 (0.035)

Variable	Chetilla		Contumazá		Payac	
	Ben.	Non-ben.	Ben.	Non-ben.	Ben.	Non-ben.
Minimum till	0.118 (0.039)	0.118 (0.030)	0.148 (0.040)	0.234 (0.036)	0.111 (0.030)	0.104 (0.030)
Manure	0.397* (0.060)	0.269* (0.041)	0.346 (0.053)	0.319 (0.039)	0.213 (0.040)	0.170 (0.037)
Compost	0.015 (0.015)	0.000 (0.000)	0.012 (0.012)	0.000 (0.000)	0.113*** (0.031)	0.000*** (0.000)
Mulch	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.014 (0.010)	0.009 (0.000)	0.000 (0.000)
Incorporate crop residues	0.132 (0.041)	0.109 (0.029)	0.296 (0.051)	0.340 (0.040)	0.271 (0.043)	0.255 (0.043)
Green manure	0.132* (0.041)	0.050* (0.020)	0.160 (0.041)	0.121 (0.028)	0.009 (0.009)	0.009 (0.009)
Cover crop	0.044* (0.025)	0.000* (0.000)	0.037* (0.021)	0.000* (0.000)	0.019 (0.013)	0.019 (0.013)

*, **, *** mean difference between beneficiaries and non-beneficiaries is statistically significant at 10%, 5% and 1% level, respectively

Outcomes for project beneficiaries and non-beneficiaries

Crop yields are reported in Table 7 for the crops with sufficient observations of yields for both beneficiaries and non-beneficiaries in each site, including barley and potatoes in Chetilla; wheat, maize and potatoes in Contumazá; and mangos and maize in Payac. Maize yields are substantially higher in Payac than in Contumazá, while potato yields are substantially higher in Contumazá than in Chetilla. These differences likely reflect differences between these sites in the use of irrigation for these crops. Within sites, we find no statistically significant differences in yields between beneficiaries and non-beneficiaries in either Chetilla or Contumazá. In Payac, beneficiaries have much higher mango yields than non-beneficiaries, and the difference is strongly statistically significant. Sample Payac beneficiaries also have much higher mean maize yields, although the difference is not statistically significant, due in part to the small sample size.

Table 7. Crop yields in 2008 of beneficiaries vs. non-beneficiaries
Yield in kg/ha (standard errors and numbers of observations in parentheses)

Variable	Chetilla		Contumazá		Payac	
	Ben.	Non-ben.	Ben.	Non-ben.	Ben.	Non-ben.
Wheat	NE	NE	1365.9 (188.8) (n=40)	1147.4 (182.6) (n=52)	NE	NE

Barley	309.3 (89.3) (n=20)	429.3 (118.1) (n=29)	NE	NE	NE	NE
Maize	NE	NE	592.9 (76.0) (n=25)	633.7 (171.6) (n=26)	3143.1 (416.9) (n=14)	1688.7 (416.9) (n=20)
Potatoes	634.7 (147.3) (n=32)	601.0 (118.8) (n=48)	2869.7 (765.7) (n=37)	2282.7 (425.2) (n=23)	NE	NE
Mango	NE	NE	NE	NE	8689.6*** (1228.9) (n=76)	3685.9*** (580.9) (n=68)

*, **, *** mean difference between beneficiaries and non-beneficiaries is statistically significant at 10%, 5% and 1% level, respectively
NE: Not estimated due to insufficient number of observations

Respondents' perceptions of land degradation on their parcels are reported in Table 8. Gullies, rill erosion, and landslides are commonly reported as having occurred since 1998, especially by project beneficiaries in Contumazá (these problems are reported for 20% or more of project beneficiaries' parcels in Contumazá). Soil fertility depletion is also commonly reported to be a problem, especially in Contumazá (by both beneficiaries and non-beneficiaries). In Contumazá, beneficiaries are significantly more likely than non-beneficiaries to report problems of gullies, rills and landslides since 1998, and rill erosion since 2006. Similarly, in Payac, beneficiaries are more likely than non-beneficiaries to report problems of gullies and rills, either since 1998 or since 2006. In Chetilla, by contrast, the only statistically significant difference between beneficiaries and non-beneficiaries in reported land degradation is in soil fertility change, with less soil fertility decline on average reported by project beneficiaries.

Table 8. Perceived land degradation by beneficiaries vs. non-beneficiaries
Proportion of sub-parcels (standard errors in parentheses)[1]

Variable	**Chetilla**		**Contumazá**		**Payac**	
	Ben.	Non-ben.	Ben.	Non-ben.	Ben.	Non-ben.
Number of observations	85	175	92	166	123	117
Gullies since 2006	0.024 (0.017)	0.006 (0.006)	0.076 (0.028)	0.054 (0.018)	0.073** (0.024)	0.017** (0.012)
Rills since 2006	0.035 (0.020)	0.017 (0.010)	0.109*** (0.033)	0.018*** (0.010)	0.081*** (0.025)	0.009*** (0.009)
Landslides since 2006	0.094 (0.032)	0.086 (0.021)	0.120 (0.034)	0.066 (0.019)	0.041 (0.018)	0.051 (0.020)
Gullies since 1998	0.059 (0.026)	0.040 (0.015)	0.272*** (0.047)	0.102*** (0.024)	0.146*** (0.032)	0.034*** (0.017)
Rills since 1998	0.094 (0.032)	0.091 (0.022)	0.196*** (0.042)	0.054*** (0.018)	0.138*** (0.031)	0.043*** (0.019)
Landslides since 1998	0.165 (0.040)	0.131 (0.026)	0.207** (0.042)	0.108** (0.024)	0.122 (0.030)	0.128 (0.031)
Change in soil fertility since 1998	-0.765* (0.090)	-0.947* (0.060)	-1.121 (0.085)	-1.258 (0.053)	-0.619 (0.095)	-0.725 (0.069)

*, **, *** mean difference between beneficiaries and non-beneficiaries is statistically significant at 10%, 5% and 1% level, respectively

The mean values of household consumption expenditures and income per capita are much higher in Payac than in Chetilla or Contumazá (Table 9). Contributing to this is much higher crop revenue in Payac, mostly from mango sales. In Chetilla, livestock product sales are a much more important source of revenue than crop sales, although crops are important for the households' subsistence needs. In Contumazá, livestock, wheat and potato sales are the most important revenue sources.
There are differences in income and consumption expenditures between project beneficiaries and nonbeneficiaries in each site. In Chetilla, beneficiaries earn much more from livestock product sales than non-beneficiaries. Beneficiaries in Contumazá have lower consumption and income per capita than nonbeneficiaries, due mainly to lower livestock sales. In Payac, beneficiaries have significantly higher per capita consumption expenditures, revenue from maracuya sales, and growth in total assets since 2006. They also have much higher mean income per capita, crop revenue and revenue from mango and maize sales, although these differences are not statistically significant, due to the large variance of these variables and relatively small sample size.

Table 9. Household consumption, income and changes in assets of beneficiaries vs. non-beneficiaries
Values in soles (standard errors in parentheses)

Variable	**Chetilla**		**Contumazá**		**Payac**	
	Ben.	Non-ben.	Ben.	Non-ben.	Ben.	Non-ben.
Number of observations	49	118	62	97	69	65
Monthly consumption expenditures per person	80.4 (7.3)	80.6 (5.4)	51.8*** (4.9)	81.7*** (7.2)	164.7* (11.5)	131.3* (13.4)
Annual per capita income	1529.5 (358.7)	908.6 (156.8)	806.2* (147.2)	1659.5* (437.3)	5178.6 (1325.4	2725.2 (661.3)

[1] Except change in soil fertility, which was measured using an ordinal indicator: -2=soil fertility has declined much, -1=soil fertility has declined a little, 0=no change in soil fertility, +1=soil fertility has increased a little, +2=soil fertility has increased much

					)	
Crop revenue per capita	10.8 (7.4)	25.3 (13.3)	111.2 (29.2)	187.4 (53.0)	2626.6 (1113.2)	855.5 (212.5)
Revenue from wheat sales	0.0* (0.0)	3.3* (1.7)	131.1 (38.0)	202.8 (46.1)	NE	NE
Revenue from barley sales	0.0* (0.0)	4.4* (2.3)	85.8 (55.5)	24.0 (16.4)	NE	NE
Revenue from potato sales	10.4 (6.9)	29.4 (11.0)	109.1 (43.0)	360.0 (168.8)	NE	NE
Revenue from maize sales	0.0 (0.0)	0.5 (0.0	41.1 (15.7)	34.4 (15.1)	781.6 (462.0)	340.9 (112.1)
Revenue from mango sales	NE	NE	NE	NE	3459.0 (1118.8)	1760.6 (532.7)
Revenue from avocado sales	NE	NE	NE	NE	60.7 (22.6)	107.1 (46.9)
Revenue from maracuya sales	NE	NE	NE	NE	261.7** (97.4)	18.5** (18.5)
Revenue from livestock sales	917.2 (213.4)	729.0 (136.1)	467.6** (125.7)	879.7** (166.4)	231.9 (80.8)	142.4 (36.6)
Revenue from livestock product sales	2350.9* (897.3)	684.9* (117.1)	65.0 (27.4)	38.6 (21.3)	27.5 (25.9)	0.4 (0.2)
Change in value of assets since 2006	1142.5 (832.1)	2084.5 (553.0)	500.6 (321.4)	1304.8 (1094.2)	5695.4* (2081.3)	1469.0* (495.2)

*, **, *** mean difference between beneficiaries and non-beneficiaries is statistically significant at 10%, 5% and 1% level, respectively
NE: Not estimated due to insufficient number of observations

Erosion signs in the study areas

A starting point for the analysis on the intervention of soil and water degradation is an analysis of current levels of erosion and the current practices to deal with soil and water conservation. In this section, we evaluate observed signs of erosion and practices in the three areas that were surveyed in the project. Signs of erosion were observed on many farms in the survey including rill erosion, gulley erosion, and landslides. During the farm survey only the presence of these erosion signs was registered. The intensity of erosion was not quantitatively assessed as this would involve large scale measurements. Table 10 provides an overview. In the three study sites signs of erosion were observed on approximately 55% in Chetilla and Payac and on 78% of the farms in Contumazá. For all three study areas on average 0.61-0.64 signs of erosion were found per field. A comparison of the number of erosion signs with the main environmental characteristics shows that altitude, wetness index and vegetation index do not seem to be correlated to the number of erosion signs. However, there was a significant effect of slope on the presence of erosion signs where steeper slopes resulted in more intense erosion.

Table 10. Erosion signs in the three project areas in relation to environmental parameters

Area	# of erosion signs	Altitude	Slope	Wetness index	NDVI
Chetilla	0	3214	13.3	0.26	0.65
	1	3282	14.5	0.23	0.67
	2	3229	13.7	0.23	0.70
	3	3201	17.3	0.24	0.66
Contumaza	0	2622	15.8	0.23	0.71
	1	2971	17.4	0.20	0.67
	2	3038	18.4	0.23	0.71
	3	2968	20.6	0.18	0.62
Payac	0	1022	11.2	0.30	0.79
	1	961	10.2	0.32	0.78
	2	996	11.0	0.35	0.74
	3	983	12.4	0.29	0.76

Conservation practices

Where erosion signs were common in the three study areas, conservation measures were similarly common. The conservation measures included terraces, infiltration ditches, and agroforestry practices. In Payac, the region where most fields were located in the valley with less pronounced slopes, conservation practices were implemented on 53% of the fields. In Chetilla and Contumazá conservation practices were more common on 74 and 81 % of the fields respectively. The results are shown in Table 11. Although there is a general tendency that conservation practices are found on the higher parts of the study areas, there does not seem to be a clear relationship between the occurrence of conservation practices and slope, wetness index and NDVI.

Table 11. The occurrence of conservation practices in relation to environmental parameters

Project	Region	Altitude	Slope	Wetness index	Vegetation index
Chetilla	0	3223	11.8	0.27	0.64
	1	3156	14.2	0.26	0.65
	2	3329	15.3	0.22	0.69
	3	3525	13.7	0.21	0.74
Contumaza	0	2777	16.4	0.22	0.68
	1	2622	16.7	0.23	0.70
	2	2994	17.1	0.21	0.69
	3	3169	15.5	0.28	0.76
Payac	0	956	10.9	0.33	0.77
	1	1046	11.5	0.29	0.80
	2	1140	10.6	0.29	0.74

In the above table, we evaluated the number of erosion signs and the number of conservation practices independently from each other. One can expect, however, that the implementation of conservation practices may result in a reduction of the number of erosion signs. On the other hand, one can also argue that if many signs of erosion exist, farmers tend to implement more conservation practices. The relation between the number of erosion signs and the number of conservation practices is presented in Table 12. The results clearly show that the number of conservation practices is positively correlated with the number of erosion signs. The exception is in all three project areas if 3 signs of erosion, i.e., a combination of landslides, rill erosion and gulley erosion, were encountered. On those fields the number of conservation practices seems to decline. An explanation could be that those fields are seriously degraded and as a result farmers are not investing as much in conservation practices.

Table 12. The relation between erosion signs and conservation practices

Project	Number of erosion signs	Number of conservation practices
Chetilla	0	0.88
	1	1.20
	2	1.73
	3	1.50
Contumaza	0	0.97
	1	1.40
	2	1.56
	3	1.43
Payac	0	0.65
	1	0.54
	2	0.56
	3	0.38

Tradeoff Analysis

The tradeoff analysis (TOA-MD) model assumes farmers take land use and management decision to maximize their perceived economic well being. If farmers are provided with alternative technologies like soil and water conservation techniques they may switch practices if those technologies are economically viable. Farmers' management decisions influence erosion and water consumption in the watershed but typically the off farm effects are not considered in the decision making process. Here we consider two alternative practices for each land utilization types: a non-conserving L_{nc} versus a conserving practice L_c. L_c is selected if it yields higher expected net returns than L_{nc}. Let the difference in net returns between the two practices be denoted as $\omega(p,s)$, where p represents output and input prices and s denotes the site. The farmer adopts Lc if $\omega(p,s)$ is positive, and adopts L_{nc} otherwise. We can interpret $\omega(p,s)$ as the opportunity cost per hectare, in terms of forgone returns, for adopting L_c. practices (e_s). In the analysis, we explore the potential of adoption incentives. Farmers choose practice L_{nc} and receive the expected returns of that activity or switch to practice Lc and receive the expected returns to Lc plus the adoption incentive *g(s,l)*. The MD approach described by Antle and Valdivia (2006) utilizes the assumption that the cost of production for each crop is proportional to its yield, implying that the coefficient of variation (CV) of each crop's net returns is equal to the CV of its yield. In this case, we have a spatially explicit model with a known variation in the water holding capacity and rainfall. As a result we only deal with a smaller, random component of income variation that is assumed to be normally distributed and its variance is calculated according to the following set of equations:

$$\sigma^2_\omega = \sigma^2_c + \sigma^2_{nc} - 2\,\sigma_{cnc}$$

$$\sigma^2_c = CV_c^2 \cdot v_c^2$$

$$\sigma^2_{nc} = CV_{nc}^2 \cdot v_{nc}^2$$

$$\sigma_{cnc} = CV_c \cdot v_c \cdot CV_{nc} \cdot v_{nc} \cdot \rho_{cnc}$$

Where σ^2_c and σ^2_{nc} are the variances in net returns of the conserving and non-conserving practices respectively, v_c and v_{nc} are their mean yields, and $\sigma_{c\ nc}$ and $\rho_{c\ nc}$ are the covariance and spatial correlation coefficient in net returns between practice c and nc.

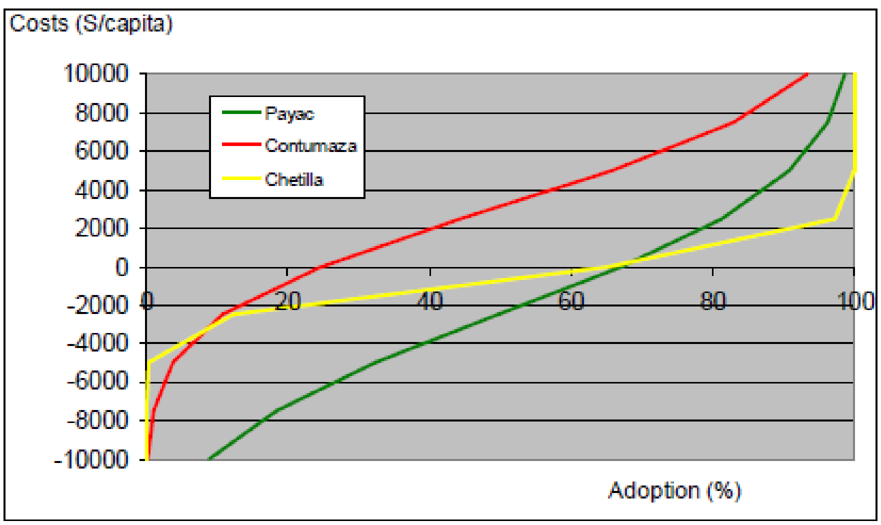
Data requirements for implementation of the TOA-MD model

If we look at the above applications and the research questions posed to us in the program, the following data need to be determined for a proper implementation of the TOA-MD model:

- A zonification of the study area based on the agro-ecological conditions. It may not be necessary to carry out this zonification if we are dealing with a relative small intervention area. However, the results will be more accurate if we are able to stratify the area to create more homogeneous area.
- The definition of the major cropping systems. In many tropical zones a multitude of different crops is being grown. As soon as we deal with the individual crops the number of observations in the survey may not be sufficient. Grouping similar crops (like the grain crops or the tuber crops in the La Encanada example) may solve this problem.
- Area estimates need to be determined for the different cropping systems and the productivities for the different systems in the different zones.
- Probably the most difficult step in the analysis is to properly assess the characteristics of the alternative system with the cost of its implementation (e.g., the cost of establishing terraces in the above example) and the effect on the productivity.

The MD_TOA model described allows us to evaluate the adoption of alternative practices. This could include, for example, soil and water conservation practices. In this research program we studied three alternative interventions dealing with organic fruit production in Payac, reforestation and terracing in Contumazá, and improved pasture management and milk production in Chetilla. Our economic analysis showed that in Payac and Chetilla per capita income was higher for those farms where interventions took place. In Contumazá per capita income was lower for the beneficiaries of the intervention programs. On the basis of these average values, one can expect that farmers in Payac and Chetilla will adopt the alternative practices and that the farmers in Contumazá will not adopt. However, the region is highly variable. This is also reflected in the variation that was observed during the farm survey in Payac, Chetilla and Contumazá with coefficients of variation above 100% for farm income. The tradeoff analysis methodology analyzes this variation and is, as a result, a suitable methodology for this type of conditions. Figure 1 shows the results of the modeling exercise. In this figure, the costs refer to the costs of adopting the alternative practice. Given the fact that we are dealing here with a cumulative curve, the adoption at a cost of zero corresponds to the percentage of farmers for which the alternative practice is actually benefitting. In the case of Conumazá, we see that 25% of the farmers have negative costs and as a result will benefit from the intervention. In the cases of Payac and Contumazá where the interventions resulted in (on average) higher per capita incomes, almost 70% of the farmers are benefitting from the alternative practice. However, the shape of adoption curves for Contumazá and Chetilla is very different. In the case of Chetilla the benefits are relatively small compared to Payac. As a result, some of the farmers may be conservative and do not want to take the risk of changing practices. Another important element of Figure 1 is the upper part of the graph. In the case of Chetilla, a relatively small incentive could lead to very high adoption rates as the alternative practice will become profitable for all farmers. In the case of Payac and Contumazá much higher incentives are necessary to make the alternative practices profitable.

Figure 1. The cumulative relationship between opportunity costs of adopting the alternative practices and the expected adoption rates.



Institutional analysis

Trust, entrepreneurship, organizational issues, and social norms are examined in the institutional analysis. Using the household survey data collected in the 3 intervention sites, these issues are analyzed in order to make comparisons between control and treatment households in each site. This analysis shows a decrease in perceived levels of trust among farmers in Chetilla associated with the intervention, while Contumaza shows increased perceived trust. Payac shows positive impacts in entrepreneurship associated with the intervention, which goes along with Cedepas' focus on commercialization in this project. An evaluation of people's perceptions of these interventions in each of the areas studied shows that the intervention in Chetilla has had a positive

impact on people's perceptions about the evolution of their community's economic situation over the last 5 years. In Payac, the intervention has had a significant impact on positive perceptions regarding the future economic situation of the community, whereas in Contumaza, the only positive impact of the intervention is in the expectation of improvement over the next five years.
The institutional analysis shows that the Payac intervention has been successful in promoting entrepreneurial attitudes amongst beneficiaries, resulting in increased confidence in their ability to improve their own economic situations. Analysis of the Contumazá intervention, on the other hand, suggests that PRONAMACHCS' use of donations to promote conservation may have lead to a failure to convince its beneficiaries of the importance of conservation practices. An examination of the Chetilla intervention shows that, in part due to a secure milk market and strong constant leadership, APROGAL is a strong organization with the ability to enforce its own rules.

Discussion

We discuss the estimated impacts of each of the projects in turn, starting with the CEDEPAS Norte livestock and pasture improvement project in Chetilla, followed by the PRONAMACHCS sustainable land management project in Contumazá, and the CEDEPAS Norte project on fruit production in Payac. For each project, we discuss the results of econometric analysis using matching methods, and consider the robustness of the results to the type of matching method used and how the matching results compare with the unmatched results discussed in the previous section.

Chetilla
In Chetilla, we find few statistically significant differences in recent land use change (from 2006 to 2008) between CEDEPAS project beneficiaries and comparable non-beneficiaries and parcels, as in the descriptive analysis discussed in the previous section using unmatched samples (Table 13). The only significant differences are a smaller likelihood of converting pastures to annual crops (both methods), and a greater propensity of beneficiaries to improve natural pastures (significant only using the NN matching procedure). These differences are quantitatively large as well as statistically significant: the probability of converting pasture to annual crops is reduced by 49% using the result of the NN procedure, while the probability of improving natural pasture is increased by 23%. These results are consistent with the nature of the project intervention, which sought to promote development of improved pastures and to improve livestock production. Since this project appears to be reducing conversion of pastures to annual crops as well as improving natural pastures, this may be having a favorable impact in reducing erosion caused by cultivating annual crops in these sloping areas. We consider the evidence on this issue further below in discussing the analysis of land degradation indicators.

Table 13. Comparisons of land use change (beneficiaries – non-beneficiaries) using matching methods
Difference in proportion of parcels (standard errors in parentheses)

Variable	Chetilla		Contumazá		Payac	
	PSM	NN	PSM	NN	PSM	NN
Annual crops in 2008 | Annuals in 2006	0.039 (0.086)	0.036 (0.117)	0.021 (0.083)	-0.038 (0.056)	-0.005 (0.184)	0.005 (0.094)
Perennial crops in 2008 | Annuals in 2006	-0.059 (0.048)	NE	-0.013 (0.036)	-0.005 (0.048)	-0.430* (0.250)	-0.206 (0.154)
Pasture in 2008 | Annuals in 2006	-0.036 (0.112)	-0.032 (0.079)	0.004 (0.057)	0.035 (0.065)	NE	NE
Fallow in 2008 | Annuals in 2006	-0.026 (0.040)	-0.110 (0.078)	0.032 (0.043)	0.038 (0.058)	0.046 (0.092)	0.053 (0.065)
Perennial crops in 2008 | Perennials in 2006	NE	NE	NE	NE	-0.065 (0.057)	-0.070 (0.050)
Annual crops in 2008 | Perennials in 2006	NE	NE	NE	NE	0.014 (0.142)	0.073 (0.120)
Fallow in 2008 | Perennials in 2006	NE	NE	NE	NE	-0.008 (0.016)	NE
Pasture in 2008 | Pasture in 2006	-0.108 (0.161)	-0.143 (0.157)	NE	NE	NE	NE
Annual crops in 2008 | Pasture in 2006	-0.368** (0.190)	-0.488*** (0.140)	NE	NE	NE	NE
Perennial crops in 2008 |	0.035	0.067	NE	NE	NE	NE

Pasture in 2006	(0.094)	(0.070)				
Fallow in 2008 | Pasture in 2006	-0.022 (0.042)	NE	NE	NE	NE	NE
Improved pasture in 2008 | Natural pasture in 2006	0.171 (0.136)	0.227** (0.101)	NE	NE	NE	NE

PSM: propensity score matching with Epanechnikov kernel weights, bootstrap standard errors
NN: nearest neighbor matching
NE: Not estimated due to insufficient number of observations
*, **, *** mean difference is statistically significant at 10%, 5% and 1% level, respectively

The results of the NN procedure indicate that Chetilla project beneficiaries were significantly more likely to plant trees in their parcels but less likely to construct terraces than comparable non-beneficiaries on comparable parcels (Table 14). These results are different than the descriptive results of the previous section (which found insignificant differences in these investments) and were not robust using the PSM, however, with which all differences in investments were found to be statistically insignificant. Since the NN procedure corrects for bias caused by imperfect matching (using auxiliary regressions), there are good reasons to prefer the NN results, though as discussed in the methodology section, there are also disadvantages of NN relative to PSM. Since the findings are not robust across the two estimators, we have less confidence in these conclusions than if robust results were found. Nevertheless, the results suggest that the CEDEPAS Norte project has promoted tree planting, perhaps as part of pasture improvement. The finding of less terrace investment by project beneficiaries may be related to the smaller likelihood of beneficiaries to convert pastures to annual crop production, for which terraces would be more needed.

Table 14. Comparisons of land investments (beneficiaries – non-beneficiaries) using matching methods
Difference in proportion of parcels (standard errors in parentheses)

Variable	**Chetilla**		**Contumazá**		**Payac**	
	PSM	NN	PSM	NN	PSM	NN
Terrace constructed since 2006	0.001 (0.027)	-0.120** (0.052)	0.066 (0.044)	0.034 (0.074)	0.014 (0.032)	0.016 (0.021)
Infiltration ditch constructed since 2006	0.017 (0.019)	0.017 (0.020)	0.025 (0.023)	0.025 (0.026)	0.025 (0.039)	0.032 (0.029)
Trees Planted since 2006	0.089 (0.064)	0.306*** (0.092)	0.036 (0.048)	0.001 (0.076)	0.005 (0.055)	-0.031 (0.044)
Other investment since 2006	-0.019 (0.055)	-0.065 (0.039)	-0.018 (0.040)	-0.035 (0.037)	0.062 (0.110)	0.113 (0.103)
Terrace constructed since 1998	-0.045 (0.070)	-0.225** (0.105)	0.204*** (0.069)	0.085 (0.087)	-0.016 (0.043)	-0.023 (0.043)
Infiltration ditch constructed since 1998	0.086 (0.054)	0.048 (0.068)	0.070* (0.042)	0.076* (0.040)	0.021 (0.030)	0.023 (0.039)
Trees Planted since 1998	0.140 (0.094)	0.226 (0.155)	0.162** (0.065)	0.158** (0.080)	0.006 (0.049)	-0.060 (0.070)
Other investment since 1998	0.072* (0.040)	0.099* (0.059)	-0.000 (0.038)	-0.015 (0.052)	0.009 (0.043)	0.028 (0.040)

PSM: propensity score matching with Epanechnikov kernel weights, bootstrap standard errors
NN: nearest neighbor matching
*, **, *** mean difference is statistically significant at 10%, 5% and 1% level, respectively

There are few statistically significant differences in crop choice between project beneficiaries and comparable non-beneficiaries in Chetilla (Table 15). Beneficiaries are significantly less likely to plant wheat or peas in the rainy season, as in the descriptive analysis (NN only), but more likely to plant potatoes in the dry season (NN only, weakly significant, not found in the descriptive analysis). It's not clear why the project would have these associations with crop choice. Perhaps project beneficiaries are more focused on livestock production and less focused on crop production in general than non-beneficiaries, so are less likely to grow wheat and peas, which are two of the most important crops in this site. The statistically weak association of beneficiaries with dry season potato production may be a result of random variation, and may not represent any actual difference between beneficiaries and non-beneficiaries.

Table 15. Comparisons of crop choice in 2008 (beneficiaries – non-beneficiaries) using matching methods

Difference in proportion of sub-parcels (standard errors in parentheses)
PSM: propensity score matching with Epanechnikov kernel weights, bootstrap standard errors
NN: nearest neighbor matching
NE: Not estimated due to insufficient number of positive observations
*, **, *** mean difference is statistically significant at 10%, 5% and 1% level, respectively

Beneficiaries in Chetilla are significantly more likely to use several land management practices during the rainy season, including crop rotation, incorporation of crop residues and green manures (NN only) (Table 16). Greater use of such intensive practices as incorporating crop residues and green manures is not consistent with the hypothesis given above that project beneficiaries tend to be less focused on crop production. Rather, households with more livestock, such as Chetilla project beneficiaries, may be more able to use intensive practices that require animal traction, such as incorporating crop residues and green manures.

Table 16. Comparisons of land management practices (beneficiaries – non-beneficiaries) using matching methods

Difference in proportion of sub-parcels (standard errors in parentheses)

Variable	**Chetilla**		**Contumazá**		**Payac**	
	PSM	NN	PSM	NN	PSM	NN
Rainy season 2008						
Burning	0.064 (0.068)	0.006 (0.060)	-0.031 (0.087)	-0.163* (0.091)	-0.013 (0.145)	-0.358* (0.218)
Crop rotation	0.200 (0.146)	0.392*** (0.146)	-0.175 (0.125)	-0.116 (0.133)	-0.064 (0.170)	-0.539** (0.242)
Contour planting	0.067 (0.104)	0.058 (0.068)	-0.158 (0.122)	-0.273** (0.125)	-0.322* (0.185)	-0.018 (0.243)
Contour plowing	0.031 (0.069)	0.095 (0.060)	-0.245** (0.123)	-0.224* (0.115)	-0.209* (0.126)	-0.129 (0.087)
No till	-0.012 (0.055)	0.016 (0.021)	-0.012 (0.032)	0.076** (0.038)	0.098 (0.139)	-0.263 (0.189)
Minimum till	0.032 (0.130)	-0.034 (0.128)	-0.178** (0.085)	-0.037 (0.092)	0.013 (0.109)	0.044 (0.145)
Manure	-0.007 (0.109)	-0.026 (0.124)	0.102 (0.142)	-0.071 (0.140)	0.040 (0.192)	-0.105 (0.313)
Compost	0.075 (0.058)	0.095** (0.049)	0.010 (0.016)	0.013 (0.019)	0.147** (0.066)	0.054 (0.138)
Mulch	0.027 (0.024)	0.032 (0.029)	-0.010 (0.043)	-0.014 (0.022)	0.000 (0.014)	NE
Crop residues	0.131 (0.082)	0.306*** (0.092)	0.105 (0.082)	-0.020 (0.104)	-0.055 (0.150)	-0.504** (0.201)
Green manure	0.086 (0.058)	0.150** (0.072)	-0.041 (0.081)	0.099 (0.071)	0.031 (0.033)	0.043 (0.043)
Cover crop	0.032 (0.040)	0.032 (0.029)	0.032 (0.040)	0.051 (0.037)	0.037 (0.107)	0.065 (0.053)
Dry season 2008						
Burning	0.022 (0.097)	0.018 (0.179)	-0.004 (0.081)	0.034 (0.065)	-0.246 (0.205)	-0.380** (0.176)
Crop rotation	0.098 (0.117)	0.021 (0.145)	-0.028 (0.102)	-0.136 (0.085)	-0.174* (0.091)	0.015 (0.135)
Contour planting	-0.022 (0.073)	-0.070 (0.055)	-0.200** (0.091)	-0.101 (0.076)	-0.149 (0.192)	-0.002 (0.174)
Contour plowing	0.001 (0.066)	-0.046 (0.057)	-0.249*** (0.083)	-0.117 (0.087)	0.006 (0.130)	0.035 (0.101)
No till	0.008 (0.056)	0.023 (0.027)	-0.057 (0.043)	NE	0.018 (0.125)	0.006 (0.145)
Minimum till	-0.017 (0.087)	-0.099 (0.098)	-0.072 (0.105)	-0.003 (0.084)	-0.020 (0.124)	0.114 (0.169)
Manure	0.079 (0.144)	0.056 (0.155)	0.026 (0.112)	-0.023 (0.131)	-0.138 (0.116)	-0.058 (0.168)
Compost	0.023 (0.031)	0.023 (0.027)	0.014 (0.014)	0.014 (0.018)	0.089 (0.073)	0.089 (0.057)
Mulch	NE	NE	-0.021 (0.040)	-0.000 (0.023)	NE	NE
Crop residues	0.052 (0.106)	-0.001 (0.092)	-0.013 (0.101)	0.029 (0.092)	-0.025 (0.199)	0.180 (0.165)
Green manure	0.029 (0.041)	0.070 (0.056)	0.023 (0.090)	0.140* (0.071)	-0.002 (0.026)	-0.052 (0.070)
Cover crop	0.023 (0.034)	0.023 (0.027)	0.043* (0.024)	0.043 (0.031)	-0.004 (0.147)	-0.083 (0.069)

PSM: propensity score matching with Epanechnikov kernel weights, bootstrap standard errors
NN: nearest neighbor matching
NE: Not estimated due to insufficient number of positive observations
*, **, *** mean difference is statistically significant at 10%, 5% and 1% level, respectively

Barley yields are significantly higher for beneficiaries than comparable parcels of non-beneficiaries in Chetilla (NN only) (Table 17), perhaps because of greater use of the practices discussed above, or due to differences in use of production inputs. By contrast, we do not find any statistically significant differences in yields of potatoes.

Table 17. Comparisons of crop yields in 2008 (beneficiaries – non-beneficiaries) using matching methods
Difference in yield (kg/ha) (standard errors in parentheses)

Variable	Chetilla		Contumazá		Payac	
	PSM	NN	PSM	NN	PSM	NN
Wheat	NE	NE	142.2 (388.7)	-206.1 (513.9)	NE	NE
Barley	58.2 (343.7)	372.8** (172.1)	NE	NE	NE	NE
Maize	NE	NE	-217.9 (419.7)	-97.6 (239.8)	1146.9 (1568.1)	791.5 (2800.9)
Potatoes	-112.5 (355.4)	233.0 (220.0)	336.8 (2246.3)	249.4 (1391.3)	NE	NE
Mango	NE	NE	NE	NE	5097.6*** (1852.7)	5519.6*** (2094.9)

PSM: propensity score matching with Epanechnikov kernel weights, bootstrap standard errors
NN: nearest neighbor matching
NE: Not estimated due to insufficient number of observations
*, **, *** mean difference is statistically significant at 10%, 5% and 1% level, respectively

Consistent with the results reported earlier of less conversion of pasture to annual crops and more tree planting by beneficiaries, landslides have been less common since 1998 for project beneficiaries in Chetilla (NN only) (Table 18). However, perceived changes in soil fertility are also more negative for beneficiaries, despite greater use of crop rotation and incorporation of crop residues and green manures (this contrasts with the results of the unmatched comparisons discussed in the previous section, in which beneficiaries had less decline in soil fertility). These land management practices may be a response to greater perceived soil fertility depletion, though it is not clear why depletion would be greater for project beneficiaries. Perhaps project beneficiaries are more sensitized to soil fertility depletion as a problem, and hence are more likely to report it as a problem.

Table 18. Comparisons of land degradation (beneficiaries – non-beneficiaries) using matching methods
Difference in proportion of parcels (standard errors in parentheses)

Variable	Chetilla		Contumazá		Payac	
	PSM	NN	PSM	NN	PSM	NN
Gullies since 2006	0.032 (0.029)	0.034 (0.029)	0.018 (0.049)	0.016 (0.055)	0.026 (0.030)	0.039 (0.072)
Rills since 2006	0.033 (0.044)	0.144* (0.074)	0.083* (0.044)	0.099* (0.057)	0.062 (0.041)	0.063 (0.041)
Landslides since 2006	0.044 (0.085)	0.058 (0.090)	0.050 (0.056)	0.060 (0.067)	0.001 (0.088)	0.080 (0.113)
Gullies since 1998	-0.010 (0.043)	0.004 (0.053)	0.179** (0.072)	0.080 (0.078)	0.098* (0.058)	0.107* (0.056)
Rills since 1998	-0.030 (0.060)	-0.053 (0.069)	0.139** (0.062)	0.177*** (0.057)	0.064 (0.064)	0.028 (0.063)
Landslides since 1998	0.033 (0.078)	-0.353*** (0.125)	0.105* (0.059)	0.114* (0.066)	0.037 (0.049)	0.016 (0.060)
Change in soil fertility since 1998	0.131 (0.202)	-0.693*** (0.216)	0.166 (0.167)	0.261 (0.220)	0.295 (0.439)	-0.433 (0.526)

PSM: propensity score matching with Epanechnikov kernel weights, bootstrap standard errors
NN: nearest neighbor matching
*, **, *** mean difference is statistically significant at 10%, 5% and 1% level, respectively

Project beneficiaries in Chetilla earned less revenue from livestock sales in 2008 but accumulated more assets between 2006 and 2008 (NN only) (Table 19). These two results may be related; i.e., these beneficiaries may have accumulated more livestock assets because they sold less of their livestock. This could be an indication of the success of the CEDEPAS Norte livestock project in helping beneficiaries to accumulate rather than to liquidate livestock wealth.

Table 19. Comparisons of household consumption, income and changes in assets (beneficiaries – non-beneficiaries) using matching methods (S/.)
Difference in value (standard errors in parentheses)

Variable	**Chetilla**		**Contumazá**		**Payac**	
	PSM	NN	PSM	NN	PSM	NN
Monthly consumption per person	3.6 (11.1)	-12.2 (16.4)	-40.0*** (11.6)	-43.1*** (14.6)	26.5 (28.3)	40.9* (24.9)
Annual per capita income	288.6 (460.8)	295.3 (320.2)	-1241.4 (1394.5)	-286.7 (377.3)	140.2 (1712.4)	646.4 (1369.2)
Crop sales revenue per capita	-5.0 (15.3)	-17.1 (14.4)	-7.8 (127.0)	-170.3 (188.4)	-212.3 (456.6)	632.9 (414.0)
Revenue from wheat sales	-1.5 (1.5)	3.9 (4.9)	23.7 (49.7)	101.3 (58.5)	NE	NE
Revenue from barley sales	-6.9 (9.7)	-7.0 (5.3)	79.8 (81.8)	96.3 (85.4)	NE	NE
Revenue from potato sales	-28.9 (31.8)	-58.6 (24.1)	-192.7 (424.2)	-951.1 (738.4)	NE	NE
Revenue from maize sales	-0.2 (0.2)	1.4 (1.8)	16.9 (24.8)	29.4 (22.3)	-216.2 (570.0)	-238.1 (562.0)
Revenue from mango sales	NE	NE	NE	NE	63.5 (847.6)	1806.3** (889.3)
Revenue from avocado sales	NE	NE	NE	NE	40.7 (71.8)	233.3 (263.2)
Revenue from maracuya sales	NE	NE	NE	NE	113.8 (141.9)	213.0* (120.5)
Revenue from livestock sales	-168.8 (447.4)	-1546.6** (653.0)	-216.1 (299.6)	-344.3* (198.3)	-2.5 (184.3)	146.8 (180.7)
Revenue from livestock product sales	253.1 (332.7)	311.1 (288.7)	27.5 (30.6)	52.3 (35.5)	41.2 (55.6)	41.2 (53.4)
Change in value of assets since 2006	764.4 (1834.2)	2222.7* (1167.6)	-1657.5 (2574.1)	-4182.2 (3072.3)	5648.5 (4646.6)	4769.4 (4192.6)

PSM: propensity score matching with Epanechnikov kernel weights, bootstrap standard errors
NN: nearest neighbor matching
*, **, *** mean difference is statistically significant at 10%, 5% and 1% level, respectively

Overall, these results suggest that the Chetilla project has had some beneficial impacts in promoting pasture improvement and reducing conversion of pastures to annual crops, increasing tree planting and use of some land management practices, increasing barley yields, reducing some forms of land degradation (landslides) and increasing accumulation of household wealth. Nevertheless, not all indicators are positive (e.g., less investment in terraces, more soil fertility depletion), and few of these results are robust across matching methods. Hence, these results are suggestive but not definitive in demonstrating beneficial impacts of the CEDEPAS Norte project in Chetilla.

Contumazá

We find no statistically significant differences in recent land use changes between PRONAMACHCS program beneficiaries and non-beneficiaries in Contumazá (See previously referenced Table 13). As seen in the descriptive analysis in section 4, the dominant land use by far in this site is annual crop production, and changes in land use since 2006 have been rare, both for beneficiaries and non-beneficiaries. The mean differences in land use changes in the matching analysis are quite small, as well as being statistically insignificant. If PRONAMACHCS is having an impact on land degradation or household welfare, it is apparently not by affecting land use change.

Consistent with the descriptive analysis and with the nature of the PRONAMACHCS program, we find greater propensity of PRONAMACHCS beneficiaries to invest in terraces, infiltration ditches and tree planting since 1998 (See previously referenced Table 14). The impacts on tree planting are particularly large, with program beneficiaries having a 16% greater probability of planting trees on a given parcel than comparable non-beneficiaries on a comparable parcel. These findings are robust across matching methods for both infiltration ditches and tree planting since 1998 (though only weakly statistically significant at the 10% level for infiltration ditches), while the result for terrace construction since 1998 is statistically significant only using the PSM method. By contrast to these findings for land investments since 1998, we find no statistically significant difference in the probability of land investments since 2006 between beneficiaries and non-beneficiaries. This suggests that the impacts of PRONAMACHCS on land investments in this site came mainly before 2006, which is consistent with the fact that PRONAMACHCS activities in the Jequetepeque watershed have been reduced in recent years.

As in the descriptive analysis, we find few statistically significant differences in crop choice between PRONAMACHCS beneficiaries and comparable non-beneficiaries in Contumazá (See previously referenced Table 15). The only statistically significant difference is in rainy season maize production, which is less likely for beneficiaries than comparable non-beneficiaries (NN only). This result contrasts with the result of the descriptive analysis, which found little difference in the probability of maize production between beneficiaries and non-beneficiaries. It is not clear why the PRONAMACHCS program would have a negative impact on farmers' decision to grow maize.

Surprisingly, we find evidence of less use of contour plowing and contour planting by PRONAMACHCS beneficiaries in both the rainy and dry seasons (See previously referenced Table 16). The result for contour plowing in the rainy season is statistically significant using both matching methods (though only weakly significant using NN), while the other results are significant only using one method (NN for rainy season contour planting, PSM for dry season contour planting or contour plowing). These findings are similar to the results of the descriptive analysis, but are puzzling given that PRONAMACHCS seeks to promote soil and water conservation. Perhaps a focus on physical structures such as terraces and infiltration ditches has caused PRONAMACHCS to overlook the need for such agronomic measures, or perhaps such agronomic measures are less needed where physical measures are used. We investigate this issue further below using the land degradation indicators.

Besides contour planting and plowing, we find differences between PRONAMACHCS beneficiaries and non-beneficiaries in some other land management practices in at least one season, including no till in the rainy season (used more by beneficiaries, NN only), minimum till in the rainy season (used less by beneficiaries, PSM only), burning in the rainy season (used less by beneficiaries, NN only, weakly significant), green manure in the dry season (used more by beneficiaries, NN only, weakly significant), and cover crops in the dry season (used more by beneficiaries, PSM only, weakly significant). Except for the negative association with minimum till in the rainy season, most of these results indicate positive associations between PRONAMACHCS and adoption of improved land management practices such as reduced burning, no till, green manures and cover crops. However these results are not robust across matching methods and some are only weakly statistically significant, so they are more suggestive than definitive.

We find no statistically significant differences between PRONAMACHCS beneficiaries and comparable parcels of non-beneficiaries in yields of wheat, maize or potatoes (See previously referenced Table 17). This is consistent with the findings of the descriptive analysis.

As in the descriptive analysis, there is evidence of greater perceived land degradation on parcels of PRONAMACHCS beneficiaries than comparable parcels of comparable non-beneficiaries, including greater rill erosion since 2006 (both matching estimators, but weakly statistically significant), greater rill erosion since 1998 (both estimators, strongly significant), gullies since 1998 (PSM only), and landslides since 1998 (both estimators, weakly significant) (See previously referenced Table 18). These findings suggest that PRONAMACHCS interventions have not solved land degradation problems in these sloping areas, and may have made them worse. This could be due to poor maintenance of physical measures such as terraces, which can cause rather than solve degradation if poorly maintained, or lack of use of agronomic measures such as contour planting and plowing, as noted above.

However, alternative explanations for these findings are difficult to rule out. Since PRONAMACHCS sensitized program participants about land degradation problems, PRONAMACHCS beneficiaries may be more apt to perceive and report land degradation than non-beneficiaries, resulting in a reporting bias. Furthermore, PRONAMACHCS likely sought to focus on working in the more degraded or degradable areas, so a positive association between PRONAMACHCS involvement and land degradation would be expected because of this selection issue. We have controlled for observable factors such as parcel altitude and slope that could affect both PRONAMACHCS involvement and land degradation, but the indicators used may do so imperfectly and unobserved factors could still cause selection bias. If there is more degradation on parcels managed by PRONAMACHCS beneficiaries, it is apparently not enough to have caused significantly lower crop yields. Given these issues, we cannot conclude definitively that PRONAMACHCS has caused increased land degradation, although this is possible. Further research using more objective measures of land degradation can address the reporting bias issue, while addressing the selection bias issue would require further data collection (e.g., use of panel data methods to address sources of unobservable heterogeneity).

As in the descriptive analysis, we find that per capita consumption expenditures of PRONAMACHCS beneficiaries are less than those of comparable non-beneficiaries in Contumazá (both matching estimators, strongly significant) (See previously referenced Table 19). The only significant difference in income sources is in revenue from livestock sales, which is smaller for project beneficiaries (NN only, weakly significant). Income and changes in wealth are also predicted to be less for project beneficiaries, although the differences are not statistically significant due to large standard errors for these variables (variations in income are normally larger than variations in consumption). As with land degradation, there may be unobserved factors not accounted for by the matching analysis that are associated with PRONAMACHCS participation as well as poverty. Hence the association between PRONAMACHCS beneficiaries and poverty, as measured by per capita consumption expenditures, could be a reflection of targeting of this program towards poorer households, rather than the program contributing to poverty. Nevertheless, our findings do not indicate that PRONAMACHCS has helped to reduce poverty, especially given that we find no impact of the program on crop yields.

The PRONAMACHCS program has had little measurable impact on land use, crop choice or crop yields in Contumazá. It has substantially increased farmers' investments in tree planting, terraces and infiltration ditches, though these effects were mostly prior to 2006, when the program was more active. Surprisingly, PRONAMACHCS beneficiaries report more land degradation than comparable non-beneficiaries on comparable parcels, and have lower consumption expenditures per capita and lower revenues from livestock sales. These surprising findings may be due to selection bias, since PRONAMACHCS likely targeted more degradable areas and poorer households, despite the fact that the matching analysis sought to account for such differences. The fact that crop yields are not significantly different between PRONAMACHCS beneficiaries and non-beneficiaries supports the view that the project had little impact (negative or positive) on land degradation.

Payac

There are no strongly significant and robust differences in recent land use change between Payac project beneficiaries and non-beneficiaries, consistent with the insignificant results found in the descriptive analysis (See previously referenced Table 13). Of households who had annual crops on their parcels in 2006, beneficiaries are less likely to have converted those parcels to perennial crops than non-beneficiaries (PSM only, weakly statistically significant). As it focused on improving fruit production by mango producers, the CEDEPAS Norte project apparently had little impact on land use decisions.

As in the descriptive analysis, there are no statistically significant differences between Payac project beneficiaries and comparable non-beneficiaries in their propensity to make land investments (See previously referenced Table 14).

There are few statistically significant differences in crop choice between project beneficiaries and comparable non-beneficiaries in Payac (See previously referenced Table 15). Beneficiaries are more likely to produce maize in the rainy season, but this difference is found only using the NN estimator and is only weakly statistically significant.

There are several significant differences in use of land management practices between beneficiaries and non-beneficiaries in Payac, although none of these results is robust to the matching method used (See previously referenced Table 16). Beneficiaries are less likely to use burning in both the rainy and dry seasons (NN only), less likely to use contour planting or contour plowing in the rainy season (PSM only, weakly significant), more likely to use compost in the rainy season (PSM only), less likely to incorporate crop residues in the rainy season (NN only), and less likely to use crop rotation in the dry season (PSM only, weakly significant). The positive impact of the project on use of compost is as expected since the project promotes use of compost on fruit trees. Reduced burning also may have been promoted by the project. The other impacts are less expected, but these are not robust and in most cases only weakly significant.

As found in the descriptive analysis, project beneficiaries have much higher mango yields than non-beneficiaries on comparable parcels, with the difference strongly statistically significant and robust across the two matching methods (See previously referenced Table 17). This may be due to the greater use of compost by beneficiaries noted above, as well as differences in other inputs and practices not analyzed here (e.g., pest management practices). The CEDEPAS Norte project is apparently quite successful in achieving its intended impact on increasing mango production. By contrast, we find no significant difference in maize yields between project beneficiaries and non-beneficiaries, which is not surprising since the project is not focused on promoting maize production.

As in the descriptive analysis, there is a tendency for more erosion to be reported by Payac beneficiaries than non-beneficiaries, although a weakly significant difference was found only for the presence of gullies since 1998 (both matching methods) (See previously referenced Table 18). Since we found few significant differences in land use, land investments or crop choice between beneficiaries and non-beneficiaries, it is difficult to explain why erosion would be greater for beneficiaries. Furthermore, significant differences were not observed in erosion indicators since 2006, so these differences in earlier erosion cannot be attributed to the current Payac project, which began in 2006 (although earlier CEDEPAS projects in the same site might have influenced this outcome). As discussed for the PRONOMACHCS beneficiaries in Contumazá, it may be that Payac project beneficiaries are more sensitized to land degradation, hence more likely to report such problems.

As in the descriptive analysis, Payac project beneficiaries have greater consumption expenditures per capita than comparable non-beneficiaries, although this result is only weakly statistically significant and found only using the NN estimator (See previously referenced Table 19). Beneficiaries also have greater revenues from sales of mangos and maracuya than comparable non-beneficiaries (NN only, result for maracuya weakly significant), also consistent with the results of the descriptive analysis and the positive impact of the project on mango yields. Predicted impacts of the project on total income per capita and change in assets are also positive, but not statistically significant. A larger sample size would be needed to reliably estimate these impacts, given the high variance of these variables.

The CEDEPAS Norte project appears to be having a strongly positive impact on mango yields, contributing to greater revenues from mango sales and consumption expenditures per capita. The reasons for the project's positive impact on mango yields are not fully clear, although increased use of compost is likely one factor. The project is having limited impact on land use, land investments and crop choice, but is associated with less use of some land management practices, including burning and incorporation of crop residues. Surprisingly, project beneficiaries report more land degradation than non-beneficiaries, but most of these differences predate the current CEDEPAS Norte project, and may be a result of greater awareness of project beneficiaries of land degradation problems. Further research using more objective indicators of land degradation is needed to assess the extent to which actual degradation is greater on parcels of project beneficiaries, and if so, whether and how the project has contributed to this problem.

Tradeoff analysis

The Tradeoff Analysis provides a novel methodology to quickly screen for comparable agro-ecological conditions on the basis of readily available digital elevation models and remote sensing images that help to find areas of comparability. Three intervention areas that have been selected for further study in Jequetepeque have been analyzed for soil quality and erosion. No major differences in soil and erosion signs were found which is probably due to the relatively recent adoption of the alternative practices. Improved grasslands did show some increase in soil organic carbon contents but contents were also high in the non-intervention areas.

Finally, the Tradeoff analysis methodology was implemented to evaluate the adoption rates of the alternative interventions. The application shows that although the interventions in Payac and Chetilla on average are profitable, the reality is more complex. Due to the large variation in farming conditions, the interventions are only paying off for 65% of the farmers. In Contumazá, we are dealing with the opposite case where, on average, farmers are worse off when adopting but the alternative practice is still worthwhile for 25% of the farms. No major differences in soil quality were observed, probably due to the relatively recent adoption. Long term effects may still change soil quality, reduce erosion and improve productivity.

Conclusions

Our assessment of three project interventions in the Jequetepeque watershed found some significant impacts of the interventions on land use, land management, crop choice, crop yields, perceived land degradation and welfare indicators, although the types of impacts differ across the projects. The CEDEPAS Norte livestock and pasture improvement project in Chetilla and Magdalena districts appears to have reduced conversion of pasture lands to annual crops and promoted pasture improvement, increased tree planting and barley yields, reduced landslides, and increased accumulation of household wealth. Many of these findings are not robust to the matching method or strongly statistically significant, however, so are more suggestive than definitive.

The PRONAMACHCS reforestation and soil and water conservation program in Contumazá province has substantially increased investments in tree planting, terraces and infiltration ditches, although these impacts were mostly prior to 2006 when the program was more active. The program has not had measurable impacts on crop yields, and surprisingly program beneficiaries report more land degradation than matched non-beneficiaries on matched parcels. This could be a result of poorly maintained soil and water conservation measures which can cause land degradation; but this also could be due to greater awareness of land degradation among program beneficiaries or selection bias caused by "selection on unobservables". Given the limited impact of the program on crop yields, it seems unlikely that the program has had a large impact on land degradation. PRONAMACHCS beneficiaries also have lower consumption expenditures per capita and lower livestock sales than matched non-beneficiaries, which also could be caused by selection bias. So, despite clear impacts of PRONAMACHCS on adoption of tree planting and soil and water conservation measures, the impacts of this program on productivity, land degradation and poverty are uncertain, but apparently limited.

The CEDEPAS Norte organic fruit production and commercialization project in the Payac River sub-watershed has had a strongly positive impact on use of compost and on mango yields, and has thus contributed to increased revenues from mango sales and increased consumption expenditures per capita. The project has had limited impacts on land use, land investments and crop choice, but is associated with less use of some land management practices such as burning. As with PRONAMACHCS beneficiaries, Payac project beneficiaries are more likely than matched non-beneficiaries to report some kinds of land degradation, and the possible reasons for this may be similar – including reporting bias due to greater awareness of project beneficiaries of land degradation or selection bias.

With regard to the objective of reducing poverty in the Jequetepeque watershed and similar contexts elsewhere in the rural Sierra, these results demonstrate the effectiveness of promoting improved production and commercialization of high value agricultural commodities such as mangos, where there is suitable potential for such products. The Payac project has had the clearest positive welfare impacts of the three projects evaluated. Unfortunately, the potential for such high value fruit production is limited to certain areas of the lower and middle watershed with sufficient access to irrigation, and producers in these areas are already relatively well off compared to farmers in the upper watershed.

Relatively favorable outcomes were also observed for the CEDEPAS Norte livestock and pasture improvement project in the upper watershed. The fact that this project appears to help reduce conversion of pastures to annual cropping in the sloping areas of the upper watershed could be very beneficial in helping to reduce land degradation, and the findings on landslides support this. The project has also contributed to greater wealth accumulation by beneficiaries and probably to greater sales of livestock products (mainly dairy products), although this latter finding was statistically significant only in the descriptive analysis. As in the Payac case, promoting increased production of high value commodities (in this case dairy products) can yield significant benefits in improving incomes and livelihoods, although the beneficiaries again were relatively better off initially.

The evaluation results for the PRONAMACHCS intervention demonstrate the converse result that it is difficult to improve people's livelihoods by focusing primarily on soil and water conservation measures in traditional cereals and potato production systems, without emphasizing means of improving the productivity of these crops in the near term or of promoting higher value livelihood opportunities. Despite demonstrated success in promoting adoption of soil and water conservation measures, crop yields, reported land degradation, income and consumption were not measurably improved. Although it is doubtful that this program contributed to increased land degradation and poverty, for the reasons explained above, the results certainly do not provide evidence of positive impacts of the program on these outcomes. Apparently more will be needed than simply promoting tree planting and physical conservation structure to have a substantial impact on poverty and land degradation in these poor areas of the upper watershed.

These findings and conclusions support the strategy of the government of Perú and of various NGOs to promote development of the rural Sierra by identifying and promoting higher value activities linked to regional and local market development and comparative advantages. Such efforts can pay off, as they are apparently doing in Payac and Chetilla, if appropriately targeted and responsive to farmers' needs and problems. The lesson of the less successful PRONAMACHCS interventions in Contumazá province is not that efforts to promote development in such areas should be abandoned, but that a different approach is needed. More effort is needed to identify and promote technologies that can boost productivity in the near term while encouraging shifts to more sustainable and remunerative land uses and livelihood options for the poor people living in such fragile environments. A more demand led approach to technical assistance in such areas is more likely to be effective.

It is important to realize that we do not know whether income of the beneficiaries is higher due to the interventions or whether income was already higher and that the better off farmers participated in the programs. At the same time, we have to keep in mind that no major differences in soil quality and erosion signs were observed. Some of the interventions were recently implemented and as a result no major differences due to the interventions were to be expected. However, this also confirms that, at least, not only farmers on better soils did participate in the intervention programs.

This report shows the enormous variation in the Jequetepeque watershed. The variation in agro-ecological conditions is probably one of the main problems related to the adoption problem that the project is facing. A large number of projects aim to improve the livelihoods and sustainability of the cropping systems in the region. Although some of them have been successful there applicability may be limited to the variability in agroecological conditions. It certainly requires specific testing of alternative practices before they can be implemented in other parts of the watershed. The study provides a novel methodology to quickly screen for comparable agro-ecological conditions on the basis of readily available digital elevation models and remote sensing images that help to find areas of comparability.

Three intervention areas that have been selected for further study in Jequetepeque have been analyzed for soil quality and erosion. No major differences in soil and erosion signs were found which is probably due to the relatively recent adoption of the alternative practices. Improved grasslands did show some increase in soil organic carbon contents but contents were also high in the non-intervention areas.

Further applied research and technology development are needed to identify improved livelihood, land use and technology options for farmers in the upper Jequetepeque watershed and similar contexts elsewhere in the Andes. Continued development and dissemination of improved varieties of potatoes and other highland crops, improved livestock and pasture management approaches, water harvesting and other measures can have substantial impacts in helping to reverse land degradation and fight poverty in these areas. Linked to such applied research and development efforts, investments in longer term monitoring, evaluation and impact assessment of such efforts are needed to identify what works where and when, so that the lessons learned can be applied to increase the effectiveness of future programs and projects to achieve sustainable rural development and natural resource management in the rural Sierra. This study has only been able to make a start in this direction.

OBJECTIVE 2: CONTRIBUTE TO IMPROVED KNOWLEDGE AMONG POLICY MAKERS, TECHNICAL ASSISTANCE ORGANIZATIONS, FARMERS, RESEARCHERS AND OTHER STAKEHOLDERS REGARDING BEST-FIT SLWMT OPTIONS AND POLICY AND INSTITUTIONAL FACTORS AFFECTING THEIR ADOPTION IN JW

Methods

We identified policy and institutional factors affecting adoption of SLWMT options in JW and assessed and recommended options for improving the policy and institutional environment.
This strategy was to understand the policy and institutional context within which farmers and development organizations are operating in JW, to be able to diagnose problems that are preventing more effective interventions and uptake of SLWMT and prescribe promising options to address these problems. One activity was pursued in implementing this strategy: review policies, institutions and organizations affecting land and water management in JW, diagnosing the problems and recommending options to address these.

The policy, institutional and organizational environment in JW potentially have a large influence on the ability and willingness of communities and farmers to take actions that address land and water degradation in the watershed, and the ability of projects and organizations to assist in addressing these problems. For example, the Coordinadora de la Cuenca de Jequetepeque (CCJ) was seeking to coordinate actions by 6 provinces and 29 municipalities in the watershed, but has limited authority and may be undermined by recalcitrant municipal leaders or the actions of the Autoridad Autonoma, which has formal responsibility to manage the supply and use of water in the Gallito Ciego reservoir, but has not taken much action with regard to the upper watershed. We identified and assessed the different policies and institutions (formal and informal rules) operating in JW, their implementation and the organizations implementing them, to be able to diagnose conflicts and inconsistencies and recommend options for improvement.

We communicated (in both directions) with policy makers, technical assistance organizations, farmers, researchers and other stakeholders about the objectives, activities, outputs, findings and implications of the research. The communication strategy is essential to the ultimate impacts of this research project, and involves two-way communication (i.e., both in-reach and out-reach). Many of the in-reach activities (learning from stakeholders) have already been described under the previous objective and activities, and will not be repeated here. Two additional sets of activities will be used to facilitate learning from stakeholders and sharing and scaling up of lessons learned from the research:

- Conduct stakeholder consultations and workshops.
- Disseminate datasets, models, reports, policy briefs and other materials in readily usable forms.

In addition to the many consultations that were held with specific stakeholder organizations as part of the research, four stakeholder consultations were held during the course of the project. The first was the set of initial consultations with key stakeholders at the outset of the project, to introduce the project objectives and obtain input from these stakeholders concerning the relevant issues in JW and the value and approach of the project. These consultations took place during June of 2008. A more formal inception workshop was held in JW during September of 2008 to introduce the project objectives, activities and partners to a broader set of stakeholders working in the watershed, and to seek the stakeholders' involvement with the project and their feedback on the project's objectives, progress and plans. A mid-term workshop was held in March 2009 to present and discuss the preliminary findings from the household survey and the policy and institutional analysis. The final workshop was held in March of 2010 to present and discuss the findings of the CBA and TOA, and the initial impacts of the pilot interventions on adoption of SLWMT.

The activities described above have resulted in various outputs that will be disseminated through different outlets. Datasets and models have been disseminated to researchers and development partners working in JW to enable further analysis beyond what can be completed during the time frame of the project, and to strengthen the capacity of these individuals and organizations to use and build on the information collected. To the extent possible, datasets and models have been provided using widely accessible software (such as Microsoft Access and Excel). All information will be made available through publicly accessible means, including the internet, except any secondary information that is subject to intellectual property restrictions or information that must be withheld for reasons of confidentiality (like the identity and specific locations of household survey respondents).

Results

Institutional dynamics
The defining feature of institutional dynamics in the Jequetepeque basin is the contrast between a dynamic, urban, lower watershed, which has a market oriented, intensive agriculture, and the rural, poor higher watershed, where subsistence agriculture is the rule. In this context, the institutional actors of the lower region are much stronger than those located in the higher watershed. For example, while producers' organizations in the lower watershed are dominant institutional actors, with real political power and the ability to enforce their decisions, this type of organizations are extremely weak in the higher watershed. The same could be said about local and regional government agencies which are quite poor and have a very limited presence over vast portions of the higher watershed territory. In fact, it could be said that the higher watershed just does not have any dominant institutional actors, but a collection of entities with influence over very small portions of the territory and very little interaction among them (Table 22 shows an inventory of these entities). The only institutions that have actual enforcement power and, hence, are taken seriously by all other actors are SENASA (National Agricultural Sanitation Service) and PEJESA (a public project that manages the dam located in the intermediate watershed).

Table 21. Principal actors in Upper Jequetepeque Watershed

Type	Institution
Regional Government	Regional Government of Cajamarca
	Reginal Direction of Agriculture
	Local Agrarian Agencies
Local Government	Provincial Municipalities
	District Municipalities
Autonomous Public Agencies	**Proyecto Especial Jequetepeque-Zaña (PEJEZA)**
	SENASA (Ministry of Agriculture)
	National Water Authority
	PRONAMACHCS
Public-Private Entities	Coordinadora de Desarrollo de la Cuenca (CDCJ)
	Regional Environmental Council Cajamarca
NGOs	ADEFOR
	ASPADERUC
	CARE
	CEDEPAS Norte
	GRUFIDES
	GTZ
	Instituto Cuencas
Producers' Organizations	Unregulated Irrigation Users Committee (Higher Jequetepeque)
	Regulated Irrigation Users Committee (Lower Jequetepeque)
	Corn Producers Committee
	Legumes Producers Committee
	APEPAYAC
	Chirimoya Producers Association
Campesino Commun.	Four Campesino Communities
Other	Rondas campesinas
	Catholic Church

Conclusion

These findings support the strategy of the Peruvian government and various NGOs to promote the development of the rural Sierra by identifying and promoting higher value activities linked to regional and local market development and comparative advantages. Such efforts can pay off, as they are apparently doing in Payac and Chetilla, if appropriately targeted and responsive to farmers' needs. Evidence from the less successful PRONAMACHCS interventions in the Contumazá province shows that a different approach is needed. More effort is needed to identify and promote technologies in the near term while encouraging shifts to more sustainable and remunerative land uses and livelihood options for poor people living in such fragile environments. In addition, in all three projects evaluated, a high dependence of the producer organizations on the external agency support and guidance was evident. This approach appears to be insufficient, and the problems generated by the organization's lack of internal institutionalization seem to be at the heart of the project's sustainability once the external agent retires from the area.

Because of the high level of variability in agroecological conditions in the Jequetepeque watershed, it is difficult to evaluate whether different interventions are applicable in other parts of the watershed. This analysis provides a methodology to quickly screen for comparable agro-ecological conditions on the basis of readily available digital elevation models and remote sensing images that help to find areas of comparability. The tradeoff analysis was also implemented in order to evaluate the adoption rates of the alternative interventions. The analysis shows that due to the large variation in farming conditions, the interventions are only paying off for 65% of the farmers. In Contumazá, the opposite is true: on average, farmers are actually worse off when adopting but the alternative practice is still worthwhile for 25% of the farms. Although major differences in soil quality were not observed, probably due to the relatively recent adoption of practices, long term effects may still improve soil quality, reduce erosion, and increase productivity.

These findings show that one feature shared by all three interventions is the high dependence of the producer organizations on the external agency support and guidance. As far as we can tell, CEDEPAS assumed all the transaction costs related to the organization's operations and capacity building, whereas PRONAMACHCS relied on material incentives to maintain the internal cohesion of its committees. This approach appears to be insufficient, and the problems generated by the organization's lack of internal institutionalization seem to be at the heart of the project's sustainability once the external agent retires from the area. These observations suggest two things: that the particularities of each environment and social context are determinant for the intervention outcomes; and that different interventions generate different outcomes regarding institutional elements, which suggest that it is relevant to look at the origins and effects of such variables. Rural development project usually attempt to generate new—presumably more efficient—collective behaviors either by transferring knowledge through technical assistance or by providing organizational and physical infrastructure that would enable the adoption of new practices. Whereas these approaches are valid, they tend to overlook the importance of understanding the internal mechanisms through which individuals decide to change their behavioral patterns, as well as the specificities of such institutional elements in each particular environment. Failing to take into account these mechanisms and particularities during the project design stage might lead to choosing inadequate tools for fostering the desired behavioral changes. Furthermore, failing to take into account the self-reinforcement mechanisms involved in behavior stabilization may prove to be the cause for the abandonment of newly adopted practices once the project is over and the external agent that promotes them have left.

The process of disseminating information to stakeholders and policymakers is an ongoing process as the different outputs of the project are finished and there is more information to disseminate. The final workshop was conducted in March of 2010, where researchers presented the findings of their analyses and stakeholders discussed the outcomes. This discussion brought up important issues regarding the ways in which they may be able to change future interventions to incorporate what was learned in this project.

In addition, representatives from the National System of Public Investment of Peru were also briefed in several meetings on the findings of this research project. The research team is currently working with them to figure out how to implement the recommended changes in potential future interventions that go through the public investment system in the region as well as throughout the country. IFPRI will continue to follow up as well as monitor progress on these activities. In addition, the project director, Maximo Torero, will be presenting the framework behind the project in an international meeting to be held in Peru during the first week of July of 2010 for the Latin American Network of the National Systems of Public Investment.

OUTCOMES AND IMPACTS

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
PRONAMACHCS	There has been no change in practices yet, but they are aware of potential problems.	Changes in knowledge included information from the report, which was shared with actors at the mid-term and final workshops, along with discussions from their responses to reports as well as follow up with the government officials.	We included them in the project from the beginning, at workshops and in discussions, and are still keeping them involved through the dissemination of reports and other documents.	It is not possible to quantify any results yet, but if the results from this project are taken into consideration, it could have a large impact on the design of projects in the future.
CEDEPAS Norte	There has been no change in practices yet, but they are aware of potential problems.	Changes in knowledge included information from the report, which was shared with actors at the mid-term and final workshops.	We included them in the project from the beginning, at workshops and in discussions, and are still keeping them involved through the dissemination of reports and other documents.	It is not possible to quantify any results yet, but if the results from this project are taken into consideration, it could have a large impact on the design of projects in the future.
SNIP (National System of Public	There has been no change in practices yet, but they have	We presented an investment plan and a matrix from the	We used the final reports to provide them with essential	It is not possible to quantify any results yet, but

Investment in the Ministry of Economics and Finance)	been presented information on an investment plan.	typology developed to help determine best areas in which to invest.	information and have had several meetings to discuss how this information can best be utilized.	the information provided may have a large impact on where the agency invests in this region and others in the rural Sierra in the future.

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 changes above fall into two categories—PRONAMACHCS and CEDEPAS Norte actually carry out the types of interventions studied in this analysis and can potentially change the design of their projects based on the group discussions facilitated at workshops and information provided in the reports developed during this project. Because the two groups were very involved in the project from start to finish, including helping to choose the interventions that should be evaluated and assisting with carrying out the analysis, there is great potential here for their projects to be adapted based on what was learned, thus having a direct impact on the ultimate beneficiaries of these interventions.

The second category of impact is at a policy level with SNIP. Although they weren't directly involved in the selection of interventions or areas of study, the reports and information presented to them will be very useful in developing policies and determining where to invest for development projects in the future. This impact at a larger scale will also benefit the ultimate beneficiaries as investments are better targeted to the poorest households in the region that most need the assistance.

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.

We are meeting with the directors of SNIP to discuss follow-up work using the 3 impact evaluations as examples for pilot interventions to be developed. Additionally, further follow-up with stakeholders, especially those involved in projects that were evaluated, will help ensure that changes in practices result from lessons learned in this project.

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?

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

This project should have been designed with a longer timeframe to be able to carry out all of the activities that were intended. More time should also have been included to disseminate results, since that is a critical aspect of the potential impact of the project. A sufficient budget would also have been requested in order to implement possible changes in the programs through the pilot project design. We would also increase the involvement of partners in the project. As it was, we were only able to travel to the project area during the time of the workshops, but we could have increased involvement through more frequent visits to better involve stakeholders in the process. Because we traveled there so infrequently, it was extremely difficult to get people involved, get workshop attendance, and create ownership of the project and its results.

INTERNATIONAL PUBLIC GOODS

Tools and Methodology

The typology is one tool coming out of this project that can be used to determine optimal investment allocation. This tool is based on relevant criteria, including climate and topography, production, access to roads and markets, off-farm job opportunities, population density, gender distribution and the presence of various institutions, such as credit providers. These and other conditions indicate which structural problems will affect a particular micro-region and how. This typology can be used by policymakers to better understand the bottlenecks associated with the different types identified to help determine the investments necessary as well as the types of interventions likely to succeed in reducing poverty.

Additionally, the methodology developed by the team at Wageningen University and Research Center to select relatively homogeneous representative micro-watersheds for study within JW, and for extrapolating findings to similar micro-regions elsewhere in JW and in the rural Sierra is an additional tool generated that can be of value beyond the project location. It involves analyzing spatial information assembled in a Geographic Information System (GIS) on key biophysical and socioeconomic characteristics and utilizing this information to develop a typology of micro-watersheds in JW. Using available data on elevation, slope, geology, soils, climate, land cover, and access to markets and infrastructure, this methodology utilizes factor and cluster analysis methods to classify different types of micro-watersheds. This information can then be used to extrapolate findings to similar regions elsewhere in the rural Sierra, and the methodology can be adapted and used in other regions as well.

PARTNERSHIP ACHIEVEMENTS

The partnership formed with CEDEPAS Norte was crucial for the outcome of this project. From the first visit, they participated in decision-making and helped make sure the project was relevant and useful to stakeholders in the watershed. Working in collaboration with them, we were able to choose interventions to test and involve as many actors in the watershed as possible in the project. As a result of this collaboration, there is a higher potential for impact on the beneficiaries and potential for future work on these topics as well.

The collaboration with GRADE was another important partnership that was developed as a result of IFPRI’s participation in CPWF. This relationship has helped make better linkages between IFPRI and stakeholders in the region as a result of GRADE’s existing partners as well as their work carried out through the organization of meetings, workshops, and data collection in the watershed.

This was an important partnership because of the opportunity for collaboration it provided in terms of data analysis as well. In addition, GRADE is well positioned to disseminate the results of this project throughout the country and to continue to follow up with stakeholders in the watershed and in the national and regional government agencies as well.

An additional partnership was formed with the Andes Basin Focal Project (BFP) of the CPWF, which is working at a broader scale in all seven of the benchmark basins of the CPWF in the Andes. In order to contribute to improved land and water management in the Jequetepeque watershed and similar contexts elsewhere in the Andes, we coordinated with the Andes Basin Focal Project (BFP) of the CPWF in order to complement the research being led by their team. By pursuing more in-depth and quantitative data collection and modeling than will be possible in that project, we hope that the knowledge generated in our project will help them to gain more in-depth knowledge on the Jequetepeque watershed that they can use in their project and that we can draw upon the knowledge base and broader modeling efforts in that project to help scale up the lessons learned from this one. To do this, we participated in the field trip coordinated by the BFP to the Jequetepeque watershed in October of 2008 as well as in their project management workshop following the field trip to gain a better understanding of the work they are doing as well as well as working together to avoid overlap.

RECOMMENDATIONS

The findings and conclusions from the impact analysis of selected project interventions support the strategy of the government of Perú and of various NGOs to promote development of the rural Sierra by identifying and promoting higher value activities linked to regional and local market development and comparative advantages. Such efforts can pay off, as they are apparently doing in Payac and Chetilla, if appropriately targeted and responsive to farmers' needs and problems. The lesson of the less successful PRONAMACHCS interventions in Contumazá province is not that efforts to promote development in such areas should be abandoned, but that a different approach is needed. More effort is needed to identify and promote technologies that can boost productivity in the near term while encouraging shifts to more sustainable and remunerative land uses and livelihood options for the poor people living in such fragile environments. A more demand led approach to technical assistance in such areas is more likely to be effective.

Further applied research and technology development are needed to identify improved livelihood, land use and technology options for farmers in the upper Jequetepeque watershed and similar contexts elsewhere in the Andes. Continued development and dissemination of improved varieties of potatoes and other highland crops, improved livestock and pasture management approaches, water harvesting and other measures can have substantial impacts in helping to reverse land degradation and fight poverty in these areas. Linked to such applied research and development efforts, investments in longer term monitoring, evaluation and impact assessment of such efforts are needed to identify what works where and when, so that the lessons learned can be applied to increase the effectiveness of future programs and projects to achieve sustainable rural development and natural resource management in the rural Sierra.

In terms of the institutional analysis, one feature shared by all three interventions is the high dependence of the producer organizations on the external agency support and guidance. As far as we can tell, CEDEPAS assumed all the transaction costs related to the organization's operations and capacity building, whereas PRONAMACHCS relied on material incentives to maintain the internal cohesion of its committees. This approach appears to be insufficient, and the problems generated by the organization's lack of internal institutionalization seem to be at the heart of the project's sustainability once the external agent retires from the area. These observations suggest two things: that the particularities of each environment and social context are determinant for the intervention outcomes; and that different interventions generate different outcomes regarding institutional elements, which suggest that it is relevant to look at the origins and effects of such variables.

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