Adoption of terraces in the Peruvian Andes

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Promotoren:	Prof. Dr. Ir. L. Stroosnijder Hoogleraar Erosie en Bodem & Waterconservering Prof. Dr. A. Kuyvenhoven Hoogleraar Ontwikkelingseconomie	
Co-promotoren:	Dr. Ir. J. de Graaff Universitair hoofddocent bij de leerstoelgroep Erosie en Bodem & Waterconservering Dr. R. Ruben Universitair hoofddocent bij de leerstoelgroep Ontwikkelingseconomie	
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	Dr. R.H. Oostendorp	Vrije Universiteit, Amsterdam
	Dr. K. Herweg	CDE, University of Berne, Zwitserland

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Abstract

Soil erosion is considered a major constraint for agriculture and thus rural development in developing countries. Therefore, many efforts are made to promote soil and water conservation (SWC) among farm households. However, adoption of SWC practices is often disappointing. This thesis analyses the adoption behaviour of farm households. Two sub-watersheds (Pacucha and Piuray-Ccorimarca) in the Andes region of Peru were chosen as research area because of the importance of SWC in these zones, and the broad experience with SWC interventions.

The main beneficial effect of terraces is the increased water availability in the soils, allowing higher crop densities and subsequently higher yields. However, the area lost due to terracing nullifies this positive effect on yield. Without changes in crop management terraces will not increase crop yields. Therefore, terracing should be combined with intensification of agriculture or with the introduction of crops with high market value. Whether terraces are financially attractive for farmers depends on their personal opportunity cost of labour. The direct incentives that farm households receive from programmes for the implementation of SWC change only slightly the profitability of the terraces.

The decision to participate in a SWC-oriented programme appeared to play a key role in the adoption process, as programme participation is by far the most significant factor determining the adoption decision. The period of presence and the targeting criteria of programmes define which farm households decide to participate. Programmes with a top-down approach have a strong influence on the adoption decision. Participants of a programme with participatory approaches have more individual control on the adoption decision. In the latter case, terraces are installed on the less degraded fields, to intensify agricultural production for home consumption. Participants of top-down programmes installed SWC practices on the rainfed and degraded fields with steep slopes that are used for extensive agriculture or pasture. Direct incentives do not result in a change in adoption effort, except for the participatory approach with farmer competitions. These competitions result in a larger share of land with terraces.

Production functions revealed that terraces do not result in a significant increase of agricultural output at household level, but they do reduce the negative effect of slope on production. In Pacucha, the marginal product of land is lower on farms with terraces while the marginal product of labour is higher. In Piuray-Ccorimarca, it is exactly the opposite. These opposite effects are explained by the performance of the factor markets. In Piuray-Ccorimarca, land is scarcer but more capital is available, resulting in a more intensive farming system. In Pacucha, the labour market and output market are imperfect, because of the remoteness of the area. Terraces have the potential to increase agricultural production and factor productivity, but whether this is of interest of a farm household, depends on the existing markets.

External intervention is indispensable for the implementation of SWC practices by farm households. However, whether farm households continue with these practices depends on the effects on agricultural production, factor productivity and existing markets. Therefore, programmes have to take into account the scarcity of production factors and the opportunities at local markets to convert increased output or increased factor productivity into cash income. As conditions differ per region, SWC interventions should be decentralised.

Acknowledgements

A soft breeze and warm sunshine give relief as I am sitting on the top of a mountain. I am enjoying the marvellous view, and take a deep breath of fresh air. The satisfaction of having reached the top is great. The hike from the valley to the top was sometimes tough. Climbing this mountain turned out to be quite an adventure…

The four and a half years of PhD research was like this climb I made in the Andes. Like many PhD-students, I did not really know what was waiting for me when I started this PhD-research. It was an expedition in an unknown area to an unknown destination. That I finally did reach my destination is thanks to many people. I am sincere when I say that I could not have done it without them.

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Just let me stay for a while, enjoying this moment and this view. At the other side I can see another mountain waiting for me to climb, to discover what will be on the other side…I take a deep breath and continue my journey…

Psalm 121

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Acronyms

CBA	Cost-Benefit Analysis
GO	Governmental Organisation
IMR	Inverse Mill's Ratio
IRR	Internal Rate of Return
LDC	Developing Country
MARENASS	Manejo de Recursos Naturales en la Sierra Sur
NGO	Non-Governmental Organisation
NPV	Net Present Value
OC	Opportunity Costs
PRONAMACHCS	Proyecto Nacional de Manejo de Cuencas Hidrográficas y de Conservación de Suelos
SWC	Soil and Water Conservation

Prologue

October 2001

This is my second day in Pacucha. I'm still impressed by the beautiful surroundings: the impressive mountains, the splendid lake, a refreshing silence and clear air. The night was cold, but the early sun beams warm my stiff body. At this moment I realise that my PhD research is now really to start… I have an appointment with Saqueo, a farmer who lives near the place where I am staying. I asked him to be my guide for the morning, which he accepted.

Being born in the Dutch lowlands, I'm exhausted after climbing a few hundred meters at this altitude of 3000 meter above sea level. I ask Saqueo whether we can sit down for a while. He looks at me a bit ironically. "Foreigners are always very fast exhausted". We take a short break, watching silently the spectacular view. While I'm catching my breath, Saqueo starts to talk about his life: "I went to Lima", he says, "in the hope to find fortune there. I worked there for several years. But everything you gain, you have to spend on food and housing. Lima is too crowded, life is unhealthy there. I returned to my village, and now I'm happy. I produce my own food. When I work, I can keep the money to buy clothes or a radio. I'm healthy and relaxed. I never go back to Lima again."

While resting, we talk about life in Pacucha. When I ask him why some farmers do not participate in programmes, he answers: "these people are lazy, they do not want to work. They only want to receive things for nothing. In the meanwhile, they are jealous of those who work hard for their living and who achieve their goals."

We continue, and I try to be strong and act as if the walk is not exhausting me. As we climb the mountain, maize and potato fields make space for fallow land and pastures with natural vegetation. In some fields I can see abandoned terraces or infiltration ditches. "These practices were installed by PRONAMACHCS, but we have abandoned them as we don't cultivate here anymore", Saqueo explains. "As there is less rain nowadays, water is lacking here, and we decided to cultivate the fields down slope where we have access to irrigation".

We reach the top of the mountain, and the view is beautiful. I'm proud I made it, but then I see women and barefooted children walking around with their livestock; this is their daily routine. Suddenly I feel a bit silly, the stupid foreigner with her mountaineering boots, who thinks she knows everything, but actually is uninformed and disabled in this environment. We walk back silently. Saqueo only spoke a few words, but he gave me an enormous amount of valuable information.

Chapter 1

Introduction

1 Introduction

1.1 Setting and problem description

Soil erosion induced by inappropriate land management practices is considered to be a major constraint to agricultural development in developing countries (LDCs) and thus also a constraint to rural development and poverty reduction (Ellis-Jones, 1999). Since the 1960s, soil and water conservation (SWC) has been of interestest to policy makers and non-governmental organisations (NGOs). The policy makers have reasons to be concerned, as the reduction in farm productivity associated with degradation can affect the aggregate supply or price of agricultural output, the agricultural income, the economic growth, the consumption by poor farm households, and the national wealth (Winters et al., 2004). However, even though the importance of conserving soil and water in order to guarantee sustainable agriculture has been recognized, and despite many efforts, the results of SWC interventions are often discouraging (Rist and Martin, 1991; Lutz et al., 1994a; Erenstein, 1999; Sanders and Cahill, 1999; Vogel, 1999).

A complicating factor of SWC is the uncertainty about the physical dimension of soil erosion and its effects, as these are difficult to measure (Warren et al., 2001) because data are not very reliable and erosion processes are complex (Blaikie, 1985; Stocking, 1987). This uncertainty about the actual extent and impact of soil erosion in physical terms, and the difficulty of evaluating it due to socio-economic differences over space and time, make it difficult to determine the economic effect of soil erosion and thus of SWC (Erenstein, 1999). Uncertainty about the profitability might be one of the reasons of limited adoption of SWC practices.

Many economists (for example: Graaff, 1996; Enters, 1998; Bunch, 1999; Giger, 1999) argue that a major reason of the non-adoption of SWC practices is that they are not cost-effective for the farmers who should apply them: the investment costs are too high, and the benefits are too low, uncertain and achieved on long-term. To counteract these disadvantages, governments and NGOs are intervening to encourage farmers to adopt SWC practices, among others by providing incentives – but with mixed results, ranging from highly effective to counterproductive (Sanders and Cahill, 1999). There have been cases where farmers have abandoned the SWC practices once the programme has withdrawn its assistance and incentives (Bunch, 1999; Giger, 1999; Sanders and Cahill, 1999). To prevent this happening, incentives must be clearly targeted and embedded into the social and economic context and the overall policy framework (Kuyvenhoven et al., 1995).

This thesis will explore the adoption process of SWC practices in order to identify the causes of failing SWC interventions. Are the technologies inappropriate? Are the incentives inappropriate? Should the farmers be compensated permanently for installing and maintaining SWC practices? This thesis will handle these questions within the specific context of the Andes region of Peru. The Peruvian Andes was chosen as the basis research area because of its variety of agro-ecological conditions, in most of which SWC is important, and because in this region there is much experience with SWC practices and various types of incentives.

1.2 Key concepts and definitions

The research done for this thesis focuses on the on-site physical and economic effects of SWC practices, and on the role of programmes on the adoption process. In this thesis the term soil and water conservation is used instead of soil conservation. The practices for soil conservation and for conserving rainwater are closely linked. Reducing soil erosion usually entails preventing splash erosion or the breakdown of soil structure, in order to increase the infiltration of rainwater and so help water conservation. Similarly, the reduction of surface runoff by structures or changes in land management will also help to reduce soil erosion (Hudson, 1987).

The SWC practices considered are mainly mechanical. Mechanical SWC practices are used to control the movement of water – and wind – over the soil surface (Morgan, 1995). Bench terraces and slow-forming terraces receive particular attention, as these are heavily promoted in Peru. Bench terraces consist of a series of alternating platforms and risers. The platforms have a slight inward inclination, in order to retain water. Bench terraces modify the slope to enable maximum infiltration of rainwater and as a consequence they reduce runoff and erosion. Slow-forming terraces form over time. These terraces consist of ditches along the contour, with an embankment upslope which is stabilised with vegetation or trees in some cases. Eroded soil settles behind (i.e. upslope) the embankment, and as this process continues, the slope gradually changes and a terrace is created (Callañaupa and Egas, 2000).

The physical effect of SWC practices is defined as the on-site effect of these practices on soil productivity and the consequent potential change in crop production. The economic effect is measured in terms of on-site profitability, as well as the change in the farm household's production system, i.e. a possible change in the allocation of production factors and/or factor productivity. Adoption is defined as the implementation of a new SWC practice by a farm household on its own farm, after hearing about or seeing it. Incentives are defined as stimulus from external institutions (e.g. market, programmes, or government) that influence the behaviour and decision-making of farm households. These key concepts are discussed in more detail in Chapter 2.

1.3 Research questions and objectives

This research has a closer look at the effects of SWC practices and the influence of incentives on the adoption of these SWC practices. It improves the insight into the complexity of SWC interventions by governments or NGOs, and the reactions of farmers with regard to conservation strategies and the use of incentives. The research aims to identify key factors for the success or failure of SWC programmes. In order to determine the adoption behaviour and effectiveness of incentives for SWC, the research focuses on the following research questions:

1. What are the physical and subsequent socio-economic effects brought about by on-farm SWC activities and how do the farmers perceive these effects?
2. Which factors are important in the adoption process and what is the influence of the SWC programme incentives?
3. Which socio-economic constraints restrain the adoption of SWC practices?
4. What are the implications of these research findings for the use of incentives in SWC interventions?

1.4 Thesis outline

In this thesis the results of four years of research are presented. It starts with a conceptual framework and problem analysis based on theory, and then continues with the empirical research findings. Chapter 2 begins by discussing the theoretical framework of the research. The physical aspects of soil erosion are explored, as well as the economic interpretation of soil erosion and SWC. Furthermore, an overview is given of the different paradigms and research approaches in adoption literature, and the use of incentives for SWC interventions is discussed. Chapter 3 describes the historical, physical and economic context of the Peruvian Andes, as this is important for the interpretation of the results. Chapter 4 describes the two research areas, the characteristics of the farm households in the research areas, and the programmes that promoted SWC practices in these areas. Chapter 5 presents the case study on the physical effects of bench terraces on soil productivity, based on yield measurements. Chapter 6 transforms these findings into a cost-benefit analysis in order to determine the profitability of these practices at field level. Chapter 7 disentangles the adoption behaviour of farm households, and the influence of programmes on this behaviour. Three different stages are distinguished to explain this process: the decision of a farm household to participate in an SWC-oriented programme, the decision to implement SWC practices, and finally the decision on how much effort (investment) is applied if there has been adoption. Chapter 8 analyses the effect of SWC practices on farm output and factor productivity at farm household level by estimating production functions. The results are discussed in the final chapter 'conclusions and outlook' (Chapter 9).

Soil and water conservation: adoption and incentives

2 Soil and water conservation: adoption and incentives

Soil erosion can seriously affect agricultural production, and as a consequence the well-being of small-scale farmers in developing countries (LDCs), as well as the economic growth and welfare at national level (Barbier, 1995; Scherr, 1999). Much research has been done on soil degradation and its prevention, as well as on the economic behaviour of farm households. Several researchers try to combine both approaches in order to come to more appropriate and sustainable solutions for the problem of stagnating or even decreasing agricultural production of small-scale farmers due to soil degradation (e.g.: Blaikie, 1985; Barbier, 1995; Eaton, 1996; Graaff, 1996; Enters, 1998; Erenstein, 1999; Pagiola, 1999).

This chapter describes the conceptual framework that is used for a case study in the Peruvian Andes, as described in this thesis. In section 2.1 the interactions between soil erosion, soil and water conservation (SWC), soil productivity and agricultural production are explained, as well as approaches in economic valuation of soil erosion and SWC. This section 2.1 provides the theoretical framework for chapters 5, 6 and 8. Section 2.2 gives an overview of adoption theories and empirical research. This section will be used as starting point for the analysis of adoption behaviour in chapter 7. Though no special chapter is dedicated to incentives, this topic will be treated throughout the thesis. Therefore, the conceptual framework of incentives within the context of natural resource management is given in section 2.3.

2.1 Effect of soil erosion and conservation on crop production

Soil is an essential input to farming (Barbier, 1995). Processes leading to soil degradation include: chemical, physical and biological degradation, and soil erosion. Soil degradation is believed to reduce the agricultural potential of the soil (Grohs, 1994; Eswaran et al., 2001) and to threaten sustainable crop production (Enters, 1998), especially in the tropical regions. The degradation of the soil is thus believed to be a major problem for small-scale farmers in the tropics who often depend on agricultural production for their living. The quantitative assessment of soil degradation has mainly concentrated on soil erosion, as the effect of erosion on the soil capacity and thus food production is the most serious type of degradation in tropical environments (Grohs, 1994; Stocking and Murnaghan, 2001). The costs of soil erosion, and thus the benefits of conservation, may be substantial in developing countries, despite relatively low returns to agriculture (Barbier and Bishop, 1995).

2.1.1 Soil erosion

The physical effects of soil erosion are felt at two spatial levels: on-site and off-site. On-site is the field or area where soil detachment takes place. Off-site effects occur when soil erosion in upstream parts has (physical) consequences in downstream areas. The on-site effects mainly include soil loss and productivity loss, whereas off-site effects are predominantly flooding and sedimentation. In general, farmers are only concerned with the on-site effects of soil erosion, as they often face problems when their agricultural production is threatened by soil erosion, whereas society is also concerned about the off-site effects. Since this thesis focuses on farm household behaviour, on-site effects of soil erosion will be considered, as these are the household's main concern.

On-site effects of soil erosion

There is often a lot of confusion in the literature on economics of soil erosion about the different aspects of soil erosion caused by water (i.e. rainfall and/or irrigation). When the rainfall intensity or irrigation rate exceeds the infiltration capacity of the soil, ponding occurs. When this takes place on sloping land, the excess water will run off due to gravity forces. In an agricultural field, three processes start that can affect the agricultural production: water is lost (the runoff water); in some cases seeds and fertilisers are lost, as they are carried away with the runoff water; and soil erosion starts, as soil particles are detached and transported with the runoff water as well. The first two processes have a demonstrable direct effect on the crop production, as less inputs (water, and in some cases fertilisers and seeds) will be available for plant growth. The latter process has a less visible effect on crop production. Lal (2001) categorises the loss of water and inputs as short-term productivity effects, and soil erosion and its consequences as long-term productivity effects.

Soil erosion changes the soil productivity, as soil characteristics are affected. Soil productivity is reduced by soil erosion due to: reduction in rooting depth, reduction in plant-available water reserves, degradation of soil structure, and loss of nutrients. The degradation of soil aggregates, which is the basic unit of soil structure, is both a cause and a consequence of soil erosion. It is a vicious circle: degradation of soil structure is one of the causes of accelerated erosion, causing a deterioration of structural properties (Flörchinger, 1998).

A simplification of these processes is depicted in Figure 2.1. Often farmers are most concerned about the short-term visible effects: the loss of water and inputs. Water loss is a problem in particular for rainfed farming, especially in semi-arid regions, as water is often the major limiting factor for crop production (Pimentel, 1993). Loss of inputs is seen as an extra production cost. Farmers notice also a decrease in soil productivity, but it is not always directly linked to the soil erosion processes that take place in their fields. Soil productivity determines the potential crop production and thus the value of the soil for farmers, especially for farmers in LDC's, who often do not have the means to increase the soil productivity through artificial inputs (Grohs, 1994; Erenstein, 1999; Scherr, 1999).

The concern of scientists, however, is rather the soil erosion process and its consequences for the rooting depth, water storage, soil structure and soil nutrients, and how this influences the soil productivity. Especially the loss of nutrients receives attention from scientists, but distinction is not always made between nutrient losses caused by soil erosion or caused by depletion (soil mining) while these are two different processes. After soil particles are detached by the impact of raindrops, the runoff water washes away the finest and most fertile soil particles, leaving the coarse sand particles behind. This results in impoverishment of the soil and affects the soil structure. Depletion or nutrient mining occurs when the extraction of nutrients through removal of harvest products and crop residues is at a higher rate than the nutrient supply through mineralization and fertilisers (Stocking and Murnaghan, 2001). In general, the soil depletion process is less drastic than often suggested, and can be easily remedied through cultural practices and by adding fertilisers (Lal, 1990). However, this is not the case with soil erosion, as soil particles are removed selectively and permanently. The erosion effects can be masked by 'exogenous' technological change like improved crop varieties (Barbier and Bishop, 1995), or its effects are modified by the use of inputs, like nutrients in the form of fertilisers, by tillage, or by supplemental water supply through irrigation. However, adding nutrients is not a replacement for the natural productivity of the soil, as this consists of soil structure and soil depth besides the nutrients. Problems with rooting depth, which is more pronounced in eroded soils, reduce the efficiency of water and nutrient use by the crop (Hatfield, 2002).

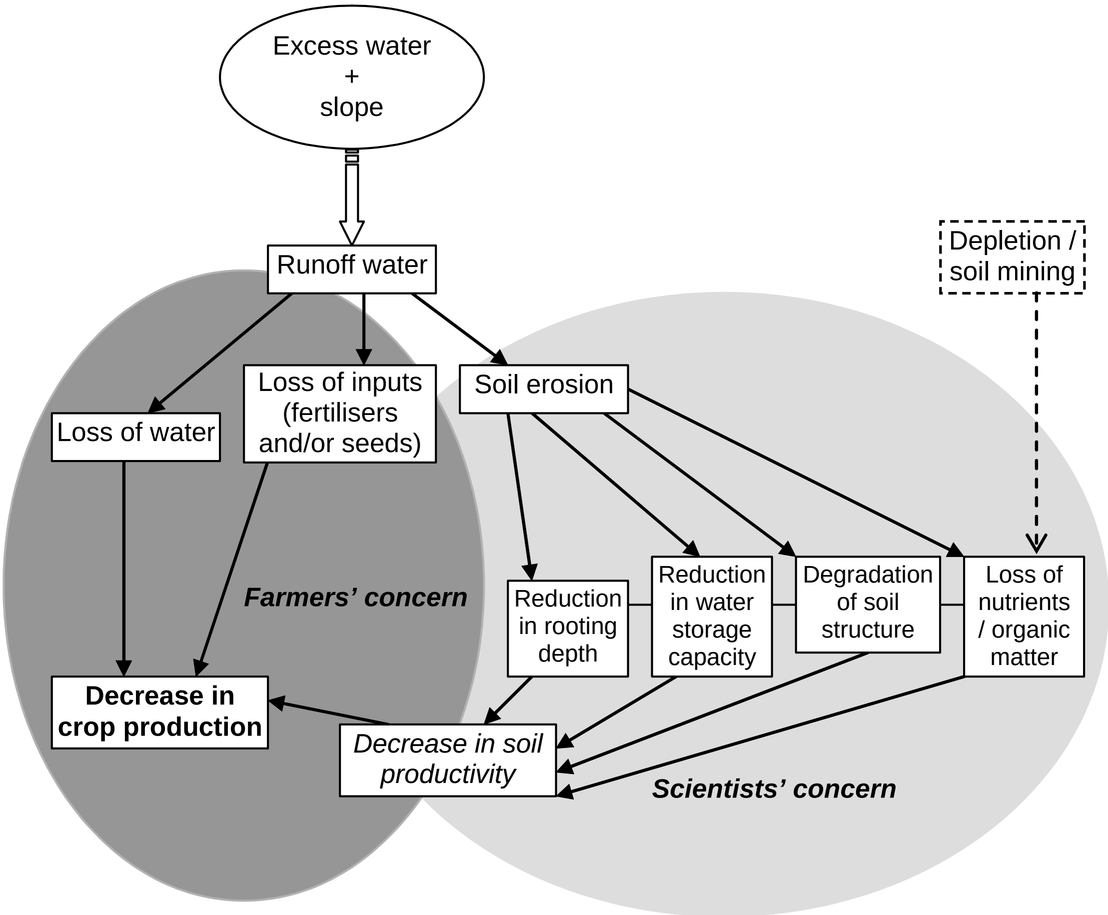

Figure 2.1 Farmers' and scientists' concerns about soil erosion and crop production

Inappropriate agricultural practices can accelerate soil erosion, and erosion-induced productivity loss is highly probable in most soils. However, any relationship between soil productivity and soil erosion depends on the *quality* of the soil that remains in the field rather than the *quantity* of soil lost (Hellin and Haigh, 2002). Erenstein (1999) also argues that erosion-induced productivity loss is more important than the amount of soil actually lost. The value of the soil for farmers is the possibility to produce crops and soil erosion results in foregone future productivity. However, quantification of this process and thus defining the effect of erosion on production is extremely difficult, as several functions of the soil are affected (see Figure 2.1). The processes are site- and time-specific. Soils differ much in their characteristics and heterogeneity is high, especially in mountainous regions. In some soils, nutrients are concentrated in the upper layers, which may lead to drastic yield losses in a few years when the topsoil is eroded. Other soils have a more even distribution of nutrients throughout the layers so that yield reductions are less pronounced and follow a more linear trend (Blaikie and Brookfield, 1987; Grohs, 1994). Furthermore, the effects vary among crops, as demands for soil structure, rooting depth and water retention differ per crop

(Grohs, 1994). The degree of soil productivity loss thus depends upon the soil profile characteristics, the crop grown, soil management, and the microclimate (Lal, 1985).

Blaikie and Brookfield (1987) enlist the following problems that are encountered during attempts to quantify the effect of erosion on productivity:

- Productivity and erosion are not independent. As one changes, so does the other, and because of the multivariate characteristics of each, so do many other factors change.
- There are other factors responsible for yield decline and productivity losses, and, although these factors may themselves be related to erosion, they are distinctly separate processes.
- Erosion rates by themselves are poor indicators of productivity loss. Some soils may suffer much erosion but are relatively unaffected, while others need only a very small quantity of soil loss to decline dramatically in yield levels.
- Changing climate, technology and inputs tend to mask the decline in land productivity.

But common sense suggests that production must be lower when soil erosion occurs, even if there is a lack of scientific data substantiating the relationship quantitatively (Erenstein, 1999). This explains the persistent assumption of erosion-induced productivity loss. Many expect the relationship to be cumulative non-linear, either convex or concave (Erenstein, 1999) or S-shaped (Pagiola, 1992). Often the regression equation that Lal found is used (Lal, 1981; cited in: Eaton, 1996):

$$Y = Ae^{-\beta x} \qquad [2.1]$$

where Y is the yield in t ha^{-1}, A is a constant (equal to yield on un-eroded land), e is the natural log, x is cumulative soil loss (t ha^{-1}) and β is a constant that varies according to crop and slope. Other attempts have been made to estimate empirically the relation between soil erosion and yield loss with empirical data (see Table 2.1). Most researchers found annual yield declines in the range of 1 to 4%.

Table 2.1 *Estimates of yield losses due to soil erosion*

Author	Country	Yield loss (%) per 1 cm soil loss	Crop and cultivation method
Lyles, 1975	USA	2.0 – 3.4	Maize
		0.8 – 3.7	Wheat
		1.6 – 2.2	Sorghum
Biot, 1989	Sierra	2.7 – 4.2	Maize
	Leone	3.3 – 4.1	Cowpea
Vittal, 1990	India	8.0	Sorghum
Grohs, 1994	Zimbabwe	2.0 – 4.2	Maize
		0.5 – 3.7	Wheat
		1.6 – 8.0	Sorghum
		3.3 – 4.1	Cowpea
Flörchinger, 1999	Colombia	3.6 – 3.7	Clean tilled fallow
		3.0 – 3.5	Cassava without ridges
		3.5	Cassava on ridges in slope direction
		3.0 – 3.5	Cassava on contour ridges

(Sources: Grohs, 1994; Flörchinger, 1998)

In order to evaluate the effect of soil erosion on soil productivity, the following approaches can be distinguished:

Statistical methods:

- *Topsoil removal* is applied to create various topsoil thicknesses. This method uses a proven statistical design with replication. However, natural soil erosion is a selective process, and the gross one-time, mechanical removal of topsoil does not simulate natural conditions (Olson et al., 1994).
- *Paired comparisons* between selected fields with different eroded phases, is often used. This approach works best in relatively young landscapes with documented cropping history where it is possible to determine estimates of past erosion. However, the data interpretation in such studies may be confounded by other factors (Olson et al., 1994).
- *Regression analysis* can be used to analyse time series of yield trends across regions in a country to identify statistically significant effect of erosion rates on yields (Grohs, 1994).
- *Geo-statistics* analyses the spatial variability of given soil and crop parameters within a specific area. When spatial variance structure occurs between samples taken from known locations in a field, it can be presented in a semi-variogram and missing values and values of correlated variables can be programmeed. The geo-statistical approach allows to express soil property changes in mathematical terms (Olson et al., 1994).
- *Production functions* can be used to estimate relationships between the soil at a given location and the accompanying crop yields. These relationships can be used to express the soil productivity at different locations with a given level of technology (Grohs, 1994).

Nutrient and water balances. The in- and outflows of nutrients and water in the soil are calculated, in order to see whether these flows are in balance, and to quantify the contribution of erosion. In case of a negative balance (more out- than inflow), the soil degrades. However, it is difficult to separate and quantify the leaching, erosion and depletion processes.

Soil-plant simulation models. These models simulate plant growth on the basis of daily climatic information for a specific location and specific crops, and allow the simulation of erosion (Grohs, 1994). EPIC (Erosion Productivity Impact Calculator) is such a simulation model. The EPIC is a process based model that operates on a daily time step and consists of components that simulate erosion, plant growth and related processes and economic components to estimate the effects and costs of erosion and to determine optimal management strategies (Flörchinger, 1998). However, these models are very data demanding and have to be validated with experiments (Olson et al., 1994; Erenstein, 1999).

Some scientists state that soil erosion is not a major threat to production (Hellin and Haigh, 2002) or that the extent of land degradation is overestimated (Mazzucato and Niemeijer, 2001). According to Erenstein (1999), this belief is based on simple before-after comparisons where achieved yield increases took place due to yield-enhancing technical progress despite of soil erosion. However, yield-enhancing technical progress cannot be seen as a simple substitute for erosion control. On the other hand, there exists a risk of overestimating erosion-induced productivity loss. Nevertheless, soil productivity often increases due to SWC practices, whether soil erosion is a serious threat to agricultural production or not.

Off-site effects of soil erosion

Water-induced soil erosion can be seen as a redistribution of soil: soil is removed from the upstream source and 're-appears' further downstream. There are many possible downstream or off-site effects (sedimentation problems in fishery, irrigation systems, and drinking water reservoirs) of soil erosion that result from surface runoff and sedimentation. This can either have negative effects, like pollution or silting up of water reservoirs, or in some cases positive effects, like enriching of the soils in alluvial plains (Sfeir-Younis and Dragun, 1993; Erenstein, 1999). Off-site costs vary in measurability and relevance. Some are a direct financial burden, like the costs of sediment removal from water reservoirs and from rivers to maintain navigation, or removal of eroded soil from roads after floods (Hatfield, 2002). Other off-site costs are less tangible and do not lend themselves for quantification.

Economic costs can be measured in terms of the present value of foregone net economic benefits from any loss of downstream economic activity, or from any direct welfare effects (Barbier, 1995). Environmental effects from erosion may take more time to be noticeable. Sediment deposition into streams, rivers, and lakes affects the biological health of the ecosystem. Sediment that is moved off-site may contain nutrients (in particular phosphorus), agricultural chemicals, or pathogens. Each of these components has an impact on the ecosystem (Hatfield, 2002). However, the contribution of erosion on agricultural land to downstream problems is often overstated, as other causes of erosion are neglected, like natural processes and non-agricultural activities like road construction and deforestation. Finally, high off-site costs do not necessarily coincide with high on-site soil erosion rates (Erenstein, 1999).

2.1.2 Soil and water conservation

The aim of soil and water conservation (SWC) is preventing or at least reducing the effects of soil erosion and maintain the soil quality (Graaff, 1993). SWC consists of any set of measures and practices in order to ensure the soil functions for long-term use by humans and nature (Grohs, 1994) and obtain a sustainable agricultural production. SWC practices can be divided into mechanical and biological practices (Hudson, 1981). Mechanical practices control soil erosion, after the soil starts moving. Biological practices, however, prevent erosion by intercepting raindrops and thus not allowing the erosion process to start (Sfeir-Younis and Dragun, 1993). However, this distinction is not as strict, as hedgerows are biological methods, but control erosion instead of preventing it. SWC practices can be subdivided into annual practices and one-time investments. Annual SWC practices form part of ploughing and cultivation practices, and require an effort within each cropping season. Annual SWC practices are: mulching, contour ploughing, organic fertilisers, cover crops, crop rotation, et cetera. One-time investments are mainly mechanical practices. They require a one-time investment of labour and capital, and afterwards recurrent maintenance activities. It often involves modification of the slope, like terracing, and preventing runoff water through infiltration ditches, benches, hedgerows, et cetera.

When replacing soil erosion by soil and water conservation in Figure 2.1, a similar picture is obtained (see Figure 2.2). The major benefits of erosion control are conserving water and retaining soil nutrients and organic matter, as well as maintaining soil depth (Pimentel, 1993) and soil structure. SWC practices decrease the risk of soil erosion and/or increase crop production. Due to

SWC practices, runoff water is retained as well as the seeds and fertilisers, and thus production costs are reduced. More fertilisers will be available to the crop increasing crop production. When the soil is conserved, there is no decrease in the rooting depth and the water storage capacity is maintained. Also, nutrients are conserved on the field. Due to the prevention of water loss, i.e. water conservation, water can infiltrate and is stored in the soil profile. In case a dry spell occurs during the rainy season, the crop benefits from the increased water storage, reducing the risk of crop failure due to drought. Water conservation is an important adjunct to soil conservation, in particular in semi-arid zones (Graaff, 1993) with rainfed agriculture. All these effects of SWC increase the soil productivity and thus the crop production. However, these SWC-induced processes can be masked by climatic changes, pests and diseases, technology changes, et cetera. There are more factors that influence crop production besides the few related to SWC that are mentioned here.

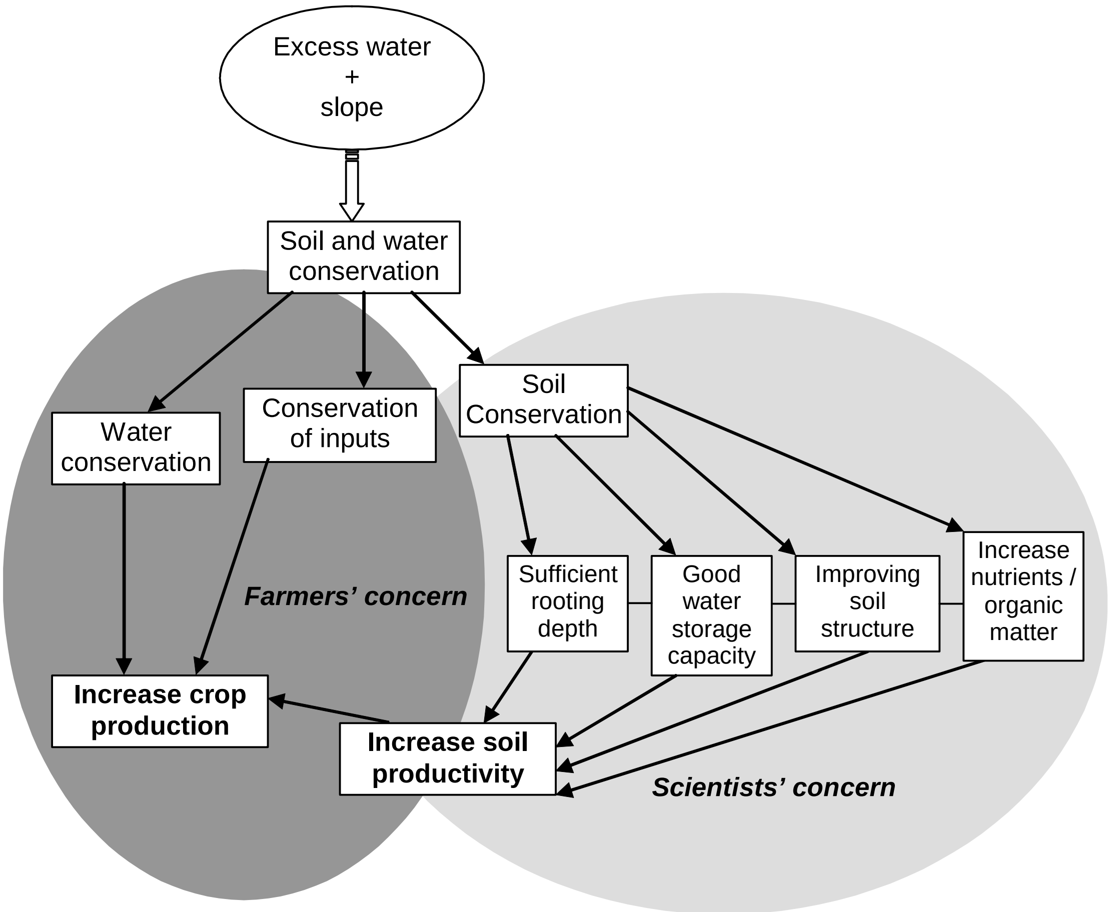

Figure 2.2 Farmers' and scientists' concerns about SWC and crop production

In this thesis SWC practices will be evaluated by their effect on soil productivity in terms of crop production. The effects of erosion and SWC on soil characteristics, as depicted in the Figures 2.1 and 2.2, are not analysed, as it is assumed that these characteristics converge in the term soil productivity.

2.1.3 Economic assessment of soil and water conservation

The assessment of soil and water conservation poses a considerable analytical challenge that can be tackled in varying ways. Erenstein (1999) distinguishes two different schools of economic analysis of soil and water conservation with their own analytical approach: (1) the evaluation school, and (2) the adoption school. The first tries to quantify the economic effect of different SWC scenarios. The latter tries to explain and predict the divergences in SWC behaviour between economic agents. The evaluation school is discussed in this section. The adoption school will be discussed in section 2.2.

Dimensions of the economic assessment of soil and water conservation

Any economic analysis of soil erosion usually begins with the assessment and quantification of the physical effects, followed by the evaluation of soil productivity decline which is commonly represented by crop yields (Sfeir-Younis and Dragun, 1993; Grohs, 1994). SWC practices change the distribution of soil and water resources in space and time. When evaluating the benefits and costs of SWC, four basic factors should be considered. The first two refer to the spatial characteristics of costs and benefits, that is, the on-site and off-site or downstream effects. The other two refer to the temporal characteristics, that is, the present value of programmes in which benefits and costs extend into a reasonably well-known future, and the optional value of actions that extend into an essentially unknown future (Seckler, 1987).

Considering the temporal aspect, SWC implies saving soil for future use: the resource use rates are distributed into the future. Degradation implies a redistribution of resource use rates towards the present (Barbier, 1995). The question is to which extent this 'redistribution in time' is desirable. SWC can be implemented at different intensities. Erenstein (1999) distinguishes the following three different connotations:

- Absolute conservation: assuring that the soil does not erode at all.
- Standards-based conservation: on-site standards take the soil formation rate into account, technology based standards take the best available control technology.
- Efficient or optimal conservation: soil erosion is prevented only if benefits are larger than the costs.

The optimal level of SWC in economic terms is the level at which the marginal benefits of additional conservation just equal its costs. It is clearly not optimal to reduce erosion to zero. Soil conservation represents a capital investment that does not necessarily generate a new income flow, but rather reduces the rate of decay of an existing income flow. Especially physical structures like terraces imply a long payback period. While the investment costs of SWC are readily determined, measuring the benefits is more problematic (Erenstein, 1999).

As for the spatial aspects, farmers are often concerned with the on-site costs and benefits of soil erosion only, whereas society is also concerned with any off-site costs (Barbier, 1995). When soil erosion and conservation is examined from the society's perspective, these external effects should be included. As a result, more costs and benefits are included for the society than for an individual farmer. The value of the resources should be adjusted for any distortions resulting from policy interventions or market failures in order to measure their true opportunity cost from a society's perspective. From a farmer's perspective, only the costs and benefits that actually accrue to the land user, who makes the decision about resource use, are considered (Lutz et al., 1994a).

On-site costs of soil erosion

From farmers' perspective, the costs of erosion control consist of two components (Barbier, 1995):

- Direct costs: the costs to the farmer of the effort that is required to undertake SWC practices for soil erosion prevention.
- Foregone output: any loss of current output that results from using less land, as SWC practices often take space.

For the on-site cost of soil erosion to be a financial cost it must be an opportunity cost, which is defined as the value of a foregone alternative. In the case of soil erosion, the alternative for the farmer is to invest in SWC. Thus, the on-site cost of soil erosion is the difference between the (present value of) net returns of the farming system with SWC and the (present value of) net returns with soil erosion (Barbier, 1995).

The valuation of erosion in monetary terms is even more complicated than the quantification of its effect on crop production. Whereas the biophysical environment determines the magnitude of soil erosion and its on-site effect, the socio-economic environment determines its value and thus its seriousness in monetary terms. An erosion-induced yield decrease is not the same in economic sense for all locations, as the value of agricultural production is influenced by factors like market access and land use (high value vs. low value crop). In developing countries most farm households are only partially integrated in markets, and particularly the staple food production is relatively inelastic. Market integration, even if partially, helps to mask the effect of soil erosion as external input use is stimulated, and market fluctuations hide trends. Market prices may, or may not, reflect the opportunity costs, and these influence farmers' behaviour (Erenstein, 1999). Under perfect circumstances, market prices represent equilibrium between supply and demand. However, in case of imperfect markets – due to lack of information, limited access, subsidies or taxes – market prices might be inadequate to reflect the economic value of goods and services. Adjusted prices are then used to express the value of these goods and services. Shadow prices are adjusted market prices, to reflect true scarcity in the economy. Surrogate market prices are often used as shadow prices. If costs and benefits are not valued in the market, but clear substitutes exist, one can use appropriately adjusted market prices for the substitutes to develop surrogate or proxy values. Another possibility is to use hypothetical values through contingent valuation (Gregersen et al., 1987).

Valuation techniques for soil and water conservation

The following valuation techniques are commonly used to assess the costs of soil erosion as well as the cost and benefits of soil conservation. Different prices are used for these valuation techniques (Gregersen et al., 1987):

<u>Using market prices:</u>

- *The change in productivity approach* calculates the difference in crop yields with and without erosion, multiplied by the monetary value of the crop, minus the production costs (Barbier, 1995). This approach is frequently used in environmental economics. There are two possible ways to apply the change of productivity approach for the assessment of soil erosion costs. The potential yield loss due to soil erosion can be estimated first and then evaluated by comparing the actual yield on an eroded soil with the yield on a conserved soil. Another possibility is to compare the increased production from actually conserved land with the production on non-conserved land to identify the actual yield loss attributed to soil erosion (Grohs, 1994). Following this approach, erosion damage equals the market value of the lost crop production. However, contributing the observed yield declines only to soil erosion results in cost overestimates (Enters, 1998), as other factors that might contribute to yield decline are overlooked.

– *The replacement cost approach* uses the value of the compensation costs when land substituting inputs like fertilisers are used to compensate for the soil degradation (Erenstein, 1999). The 'replacement cost approach' calculates the costs that one has to make when the damaged asset has to be replaced (Grohs, 1994), which is usually the annual marginal costs of fertiliser in order to compensate the loss of soil nutrients due to erosion. The replacement cost approach is appealing but can be misleading, as the interactions between soil erosion, nutrient loss and productivity loss are simplified. Most studies rely on the cost of inorganic fertiliser, not on the actual cost of nutrient replacement, which would also include the cost of transporting the fertiliser to the field as well as its application.

Using surrogate market prices

– *Hedonic pricing and property valuation* use land prices to estimate the economic value of soil erosion. Sale prices and/or rental charges of land experiencing different levels of erosion are assessed with regression analysis. The basic assumption is that investments in SWC will translate into higher land values, i.e. a future benefit to a farm household (Enters, 1998). Since land markets are poorly developed in most developing countries and institutional arrangements are often not sufficient to ensure property rights, hedonic pricing is in these circumstance of limited practical value (Grohs, 1994).

Hypothetical values

– *Contingent valuation* is often used for the valuation of environment and nature conservation. Hypothetical values are obtained through surveys by asking people how much they are willing to pay to conserve a nature reserve or to prevent air pollution. However, within SWC this method is rarely used.

Cost-benefit analysis of soil and water conservation

Cost-benefit analysis (CBA) is the most common approach to valuate the returns (or profitability) of SWC practices, and is based on the 'change in productivity approach'. In practice CBA consists of impact analysis, followed by the valuation of the various effects. This enables the comparison of the present value of the benefits to the present value of all investment and recurrent costs (Graaff, 1993). In the context of SWC, CBA generally distinguishes between a 'without-case' where soil erosion takes place, and a 'with-case' where some kind of SWC practices are implemented (Erenstein, 1999). Often a constant estimate of the yield decline induced by soil erosion over the period of analysis is assumed for the without-case. According to Pagiola (1992) this leads to biased results, as a fixed-yield decline leads to a 'front-loading' of the losses caused by erosion, causing them to be weighted more heavily in the analysis. The likely returns of conservation would then be overestimated. CBA is further discussed and applied in Chapter 6.

However, profitability does not imply that adoption of SWC will be certain. Only in case farm households operate under perfect markets and with the sole objective of profit maximisation, a CBA would be sufficient to predict adoption (Erenstein, 1999). But most farm households in LDCs maximise their utility, not profit. Utility contains the various objectives of a farm household: besides profit that can be leisure, risk reduction, social reward, et cetera. The change in utility caused by SWC practices is thus also determining the decision of a farm household to apply SWC practices or not. The composition of utility is unique for each farm household, depending on the farm household's assets, characteristics, attitude and beliefs. Adoption studies try to explain the pattern of adoption behaviour among different agents by analysing these factors. The adoption school is further explained in section 2.2.

2.2 Adoption behaviour in soil and water conservation

Since the 1950's, researchers try to understand which factors determine farmers' decision to innovate or not (Ervin and Ervin, 1982), and what determines the pattern of diffusion of the innovation through the population of potential adopters (Abadi-Ghadim and Pannell, 1999). According to many authors, results of adoption studies have been disappointing (Nowak, 1987; Abadi-Ghadim and Pannell, 1999; Boahene et al., 1999; Jones, 2002). Studies were disciplinary, lacking the expertise of different disciplines to solve the complex, multi-dimensional issue of adoption behaviour. Statistical models that were developed lack explanatory power, despite their long lists of explanatory variables (Abadi-Ghadim and Pannell, 1999). Yet much theoretical and empirical research is done to understand decision-making and adoption behaviour of farm households. This section 2.2 will be used as theoretical framework for the adoption study as discussed in Chapter 7 in this thesis.

2.2.1 Decision-making on soil and water conservation adoption

Decision-making is a complex process. Farmers' livelihood strategies are influenced or dictated by the biophysical, socio-economic and policy environments in which they operate (Blaikie, 1985; Enters, 1998). Farmers often face numerous constraints, such as land tenure problems, liquidity constraints, and the need to meet consumption requirements and to compensate for missing or incomplete markets (Lutz et al., 1994a). Within these constraints, a "room of manoeuvre" is left, in which each person can make different decisions. Final decisions are made based on own experiences and preferences, opinions of family and relatives, and other incentives. But even the decision maker himself can often not define exactly which signals influenced to what extent this decision, as some signals are received unconsciously. Each case of adoption behaviour is thus unique. The decision to adopt a new technology is a dynamic process that is determined by the characteristics of the new technology and by the characteristics of the decision maker as well. Farmers' perceptions of the relative advantages and disadvantages of the innovation, and the efforts made by extension services to disseminate these technologies also influence the adoption process (Batz et al., 2003).

In this thesis, adoption is defined as the implementation of a new or exogenous technology by a farm household on its farm. The adoption of a technology for natural resource conservation, like SWC, is different from adoption of agricultural inputs like fertilisers. The decision to adopt a new conservation technology can be seen as an investment decision on long-term, whereas the decision to apply agricultural inputs is made on a seasonal basis or short-term (Caswell et al., 2001).

Graaff (1996) and Ellis-Jones and Mason (1999) summarised a number of preconditions needed before a household considers adoption of conservation technologies (see Figure 2.3). It is assumed that farmers experience the following stages during the decision-making process: perception, need, knowledge, competence, and willingness. However, many constraints are likely to constrain the adoption behaviour of farm households.

Preconditions necessary for household adoption of conservation practices

Preconditions			*Possible reasons for no adoption*
Are erosion symptoms recognized? ↓ Yes	→	No	Very slow process More land readily available Tillage by labourers
Are erosion effects recognized? ↓ Yes	→	No	Climatic fluctuations Infrequent use or visits of land Lack of knowledge Other disturbing factors
Is erosion taken seriously? ↓ Yes	→	No	Not the farmer's land Deep soils, high fertility Considered as a downstream problem
Is farmer aware of SWC technologies? ↓ Yes	→	No	Lack of knowledge Inadequate extension Poor information flow within community
Is farmer able to undertake SWC technologies? ↓ Yes	→	No	Limited labour and capital Not land owner Socio-economic constraints Need to secure food production on short-term Incompatibility with present farming system
Is farmer willing to undertake SWC technologies? ↓ Yes	→	No	Insecure land tenure Poor financial return Benefits are too long-term Other priorities Downsteam problem
Is farmer ready to undertake SWC technologies? ↓ Yes	→	No	No adequate extension / training Too high initial investment required Too much risk Lack of credit Limited market access
Possible adoption			

Figure 2.3 Decision-making process on adoption of SWC practices (adapted from: Graaff, 1996; Ellis-Jones and Mason, 1999)

2.2.2 The adoption process according to theory

Several paradigms can be distinguished in adoption theory. Adesina and Zinnah (1993) define three main paradigms: the economic constraint paradigm, the innovation-diffusion-adoption paradigm and the adopter perception paradigm. Upadhuay et al. (2003) make a subdivision of the economic constraint paradigm into the income paradigm and the utility maximisation paradigm.

Economic constraints paradigm

Some economists assume that producers strive for profit maximisation. This implies that when an innovation or new technology results in higher profits, farm households 'automatically' adopt this technology. The strength of this paradigm lies in understanding the role of changes in income that motivates innovation. However, it fails to recognize heterogeneity among farmers' preferences (Upadhyay et al., 2003). Farm households in LDCs often opt for tolerable profits (also called satisfying behaviour), not for maximal profit. Farm households have other objectives besides profit maximisation. According to Lipton (1982), non-economic variables are more important in the decision-making of a farmer in peasant economies than economic considerations, since poverty, diseases, illiteracy, culture, and limited access to institutions change the priorities and limit the opportunities of the farmer. Objectives like risk spreading, leisure, consumption, profit, environmental protection, et cetera, congregate in the term utility. Most economic studies on adoption use therefore utility maximisation to explain farm households' behaviour. Social reward is not always considered, but this should also be included in the utility term (Boahene et al., 1999). Social status (in this case defined by non-economic variables like royalty, leadership and membership in an organization) is expected to play an important role in the adoption decision. Social networks are especially important for small-scale farmers who have less access to official institutions, as these networks enable farmers to overcome economic constraints and thus facilitate adoption.

The economic constraints paradigm assumes that resource endowments are asymmetrically distributed and this determines the observed pattern of adoption of technological innovation (Adesina and Zinnah, 1993; Negatu and Parikh, 1999). Possible economic constraints (or incentives) can be (Foltz, 2003):

- *Natural resource endowments*: increasing scarcity of natural resources (e.g. land) leads to higher shadow prices for the resource, motivating farm households to adopt a resource conserving technology.
- *Capital scarcity*: lack of capital or no access to credit implies that it is difficult for farm households to make long-term investments and thus impedes adoption.
- *Learning costs*: technologies will diffuse fastest in areas where the learning costs are low; i.e. information about technology is readily available and easily evaluated by potential adopters.
- *Risk attitude*: risk aversion implies that farmers will not invest in unknown new technologies or technologies that potentially create a greater variance in output.

The innovation-diffusion-adoption model

The diffusion paradigm is based on the innovation-diffusion theory of Rogers (1962). Rogers described the adoption process as 'the mental process an individual passes from first hearing about an innovation to final adoption' (cited in: Feder et al., 1982). Access to information about an innovation is the key factor determining adoption decisions according to this paradigm. The innovation is assumed to be appropriate, and the problem of technology adoption is reduced to communicating information on the technology to the potential adopters (Adesina and Zinnah, 1993). As the knowledge is spread over time, the new technology is adopted on a larger scale.

The diffusion theory made an important contribution to the adoption studies. The innovation-diffusion-adoption paradigm conceptualises adoption as a multi-stage decision process. Adoption is seen as a process of collecting information, revising opinions/attitudes and reassessing decisions – in other words, a dynamic learning process (Feder et al., 1982; Marsh, 1998). The current theoretical and empirical literature recognizes that adoption behaviour is complex and requires a blend of the income, utility and diffusion paradigms (Nowak, 1987; Upadhyay et al., 2003). Any adoption decision is preceded by an information acquisition period which is also called an awareness or learning period (Dimara and Skuras, 2003). Generation and distribution of knowledge (i.e. extension and training) is an important factor in the adoption process, especially in case of complex innovations (Nowak, 1987), as the decision whether to adopt or not can be seen as a 'risky choice' problem. The farmer is unsure whether he will be better or worse off by adopting (Marsh, 1998; Marra et al., 2003). One of the factors of uncertainty is on how the new technology or innovation will affect the production and/or profit. The likelihood of making a correct decision clearly depends on the decision maker's knowledge of the relevant parameters. In time, when actual yields and profit are realised with the innovation, more knowledge is gained on the new technology (Feder et al., 1982), and the innovation is perceived as less risky (Marra et al., 2003).

Adopter perception paradigm

In case of natural resource management, or more specific soil and water conservation, innovations are often more environmental (i.e. conservation) than profit (i.e. production increase or intensification) oriented. Attitude and perception play an important role in the decision-making to adopt environmental technologies besides economic considerations. To fully explain adoption behaviour, any model of the adoption process must include attitudes, motivations and perception. Before taking any action, a farmer makes an internal trade-off analysis, weighing the personal advantages and disadvantages related to the conservation decision. This internal analysis is determined by human values, which can differ per person. Farmers that are 'environmental' oriented sooner adopt a SWC technology than their 'profit' oriented colleagues. Stronger attitudes favouring soil conservation raise the levels of effort of implementation (Lynne et al., 1988).

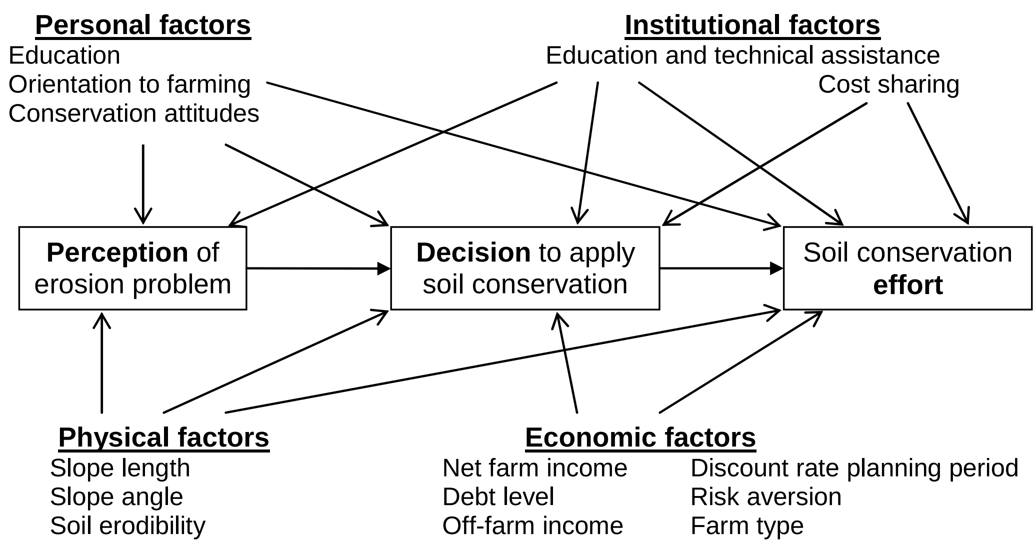

Figure 2.4 The Ervin and Ervin (1982) conceptual model of the adoption process

Ervin and Ervin (1982) tried to conceptualise the decision-making process towards SWC (see Figure 2.4). This process starts by the recognition that there is an erosion problem. This perception is influenced by personal factors (human capital) as well as physical factors of the land (physical capital) and institutional factors (awareness raising). The second stage is the decision itself whether to implement SWC practices. Besides the factors influencing the perception, also economic considerations start to play a role. In the final stage the SWC effort (a function of the extent of individual practices on the farmer's land) is determined. The same factors influence effort, but in a different way than they influence the decision to use a SWC technology (Ervin and Ervin, 1982; Semgalawe, 1998). This analytical framework links socio-psychological innovation adoption behaviour to economic decisions on SWC (Semgalawe, 1998). The conceptual model is a simplification of the adoption process, as in real life the decision process is continuous and dynamic (Sinden and King, 1990). Sinden and King (1990) included an extra step between perception and decision: recognition. A farmer might perceive soil erosion, but that does not mean that he thinks the problem is worthwhile to solve by adopting a conservation technology. Whether or not these stages should be resolved simultaneously depends on the situation. If the final stage occurs one or two years after the recognition, or if the separate effects of the factors are of interest at each stage, the models can be estimated separately (Sinden and King, 1990).

2.2.3 Modelling adoption behaviour

Uniform adoption is quite rare, as both the utility of each farm household and the constraining factors differ across socio-economic groups and over time (Feder et al., 1982). Adoption research therefore tries to determine the impact of various factors on the adoption decision by estimating empirical models on adoption behaviour. Modelling the adoption process is complicated, and the researcher often faces mathematical and also physical constraints. The theoretical or empirical model for explaining adoption behaviour also depends on the choice of the dependent variable and the available data.

Choice of dependent variable

The adoption of SWC measures has been estimated in various ways in different theoretical models. The dependent variable reflects adoption of SWC measures and ranges from a binary (or dichotomous) variable to a continuous variable like effort or intensity of use (Lynne et al., 1988). A dichotomous variable is relevant in case of non-divisible innovations (like buying a tractor or not), as non-divisible technologies are scale dependent and fixed (Semgalawe, 1998). However, important information on adoption behaviour might get lost (Lynne et al., 1988), as the dependent variable might take a value in between 0 and 1, which cannot be observed. This makes prediction impossible. In case of divisible technologies that are scale neutral and for which the level of use can be adjusted (Semgalawe, 1998), it is better to use a continuous variable.

Often, adoption is defined as a qualitative variable. It is analysed in term of whether or not the innovation is used by the farmers (Semgalawe, 1998), using probit or logit models, in which either utility functions or production functions are included. Most studies derive farmers' adoption behaviour from the maximisation of expected utility, subject to constraints like human capital and availability of land, labour, credit, et cetera (Feder et al., 1982). It is assumed that the farmer compares the new technology with the traditional technology during the decision process. If the farmers expects that the utility level of the new technology will surpass the utility of the traditional technology, he will adopt the new one (Adesina and Baidu-Forson, 1999; Batz et al., 2003). This process can be described as follows (based on the publications of: Adesina and Baidu-Forson, 1999; Batz et al., 2003):

Let EU_T represent the expected utility from adoption of improved technology T, and EU_0 the expected utility of the existing technology. The probability that a farmer adopts a new technology is a function of its relative utility:

$$P(A_T = 1) = f\left(\frac{EU_T}{EU_O}\right) \qquad [2.2]$$

where P is the probability of the adoption and A_T (=1) the adoption of the new technology. When $EU_T > EU_0$ the farmer adopts the new technology. Otherwise, no adoption is observed. The expected utility is determined by a vector X, representing the beliefs of the farm household regarding the characteristics of the technology (X_T), the characteristics of the farm household (X_H), the farming system (X_F) and the farming environment (X_E):

$$EU = f(X_T, X_H, X_F, X_E) \qquad [2.3]$$

Then, the probability of adoption is given by:

$$P(A_T = 1) = f\left(\frac{X_T}{X_O}, X_H, X_F, X_E\right) \qquad [2.4]$$

Time-series versus cross-section data

The approach used to study the adoption problem, depends on the type of data available. In time-series studies the shape of the diffusion process (or aggregate adoption behaviour) can be determined. The pattern of the aggregate adoption model is in general assumed to be a logistic-shaped (S-curve) over time. Though the decision-making of farmers to adopt a new technology is a process over time, empirical research often applies a static analysis with cross-sectional data. In these cross-sectional studies a snapshot is taken of farm households' technology use at a given moment. Using a binary choice model, the effect of farm, technology and environment characteristics on adoption decisions are estimated. However, static adoption studies often ignore the fact that most decision-making processes concerning innovation involve a multistage procedure of organisational change (Dimara and Skuras, 2003). A static model is thus problematic if the adoption decision has a dynamic structure over time. At the moment of study the technology may not yet be completely diffused throughout the population. Panel data, however, allow to combine both data and study both household effects and adoption over time (Besley and Case, 1993).

Household modelling

In some studies a household model is used to simulate the decision-making of a farm household. In order to reflect decision-making correctly, the model must be able to consider specific production constraints of a farmer while correctly weighing his main objectives (Bernet et al., 1999). In their model, Bernet et al. (1999) maximise the annual farm-household profit as a result of the optimal solution, referring to the maximum expected profitability to be reached within a specified context, as determined by a set of potential production activities and production constraints.

Disciplinarity

Several disciplines study adoption behaviour. Though adoption behaviour is subject to a combination of social, economic as well as cultural factors, most of the theoretical models have tended to present single-discipline explanations. Adoption has been explained in terms of the profitability of the investment (economics), the social rewards associated with adoption and the nature of communication channels (sociology), spatial differences in resource endowment (geography) and the compatibility of the innovation with the norms of the society (anthropology). These different approaches are complementary, and not necessarily contradictory (Boahene et al., 1999).

Many attempts are thus made to estimate adoption behaviour, using different modelling techniques. The following section discusses the results of these attempts, and the factors found empirically that determine adoption behaviour.

2.2.4 Determining factors of adoption according to empirical research

It is increasingly recognized that the technical solutions offered by external agencies are not always sustained by farmers in the long-term. It is widely accepted that, besides the bio-physical context and technical factors, the socio-economic and cultural context have to be taken into account as well (McDonald and Brown, 2000). In general, it is assumed that the adoption process is influenced by factors as technology characteristics (performance, risk, complexity, investment, appropriateness), farmers' attitude towards risk, adoption costs (investment), availability of capital (cash resources and access to credit; natural, social and human resources), labour availability and land tenure (Feder et al., 1982; Carter, 1995; Ellis-Jones and Mason, 1999; Batz et al., 2003). The following factors were found empirically to affect adoption of SWC practices significantly:

Physical factors:

- In some cases it was found that the rate of *land degradation* positively influences the adoption of SWC technologies (Sinden and King, 1990; Marsh, 1998; Baidu-Forson, 1999).

Technical factors:

- The new technologies proposed should be *appropriate* within the given farming system and not too complex (Marsh, 1998; Bunch, 1999).
- Because of lack of creativity in developing new technologies, often a *limited number of technologies* is introduced which might be appropriate at one place, but inappropriate at another (Bunch, 1999).
- The *focus* of soil conservation technologies is often on structures and retention rather than vegetation and cover, whereas the latter are more effective in preventing soil erosion, are less expensive and can provide lateral benefits (Bunch, 1999). It is better to have a broader focus like land husbandry or sustainable rural livelihoods approaches (McDonald and Brown, 2000).

Personal factors:

- *Perception*: recognition of soil erosion and positive attitude towards soil conservation influences the farmer's attitude and increases his effort in soil conservation (Lynne et al., 1988; Shiferaw and Holden, 1998).
- *Subjective preferences* for characteristics of new agricultural technologies are important determinants of adoption behaviour (Adesina and Baidu-Forson, 1995).
- *Human capital* (e.g. education, experience) influences positively the attitude and perception of the farmer, and his adoption behaviour (Feder et al., 1982; Marsh, 1998; Illukpitiya and Gopalakrishnan, 2004; Lapar and Ehui, 2004). Especially education is found to stimulate

significantly adoption of innovations in many studies (Asfaw and Admassie, 2004). Age is found to influence the adoption decision negatively in some cases (Shiferaw and Holden, 1998).

Economic factors:

- *Profitability* is a prerequisite. The new technology itself should be appropriate and provide economic advantage to farmers (Cary and Wilkinson, 1997; Marsh, 1998; Bunch, 1999), or result in a higher utility level than the traditional technology (Batz et al., 1999). The benefits (production, risk reduction, income) should be immediate and tangible (McDonald and Brown, 2000).
- Often a new technology implies an initial investment for its implementation. *Access to capital* and/or c*redit* influences the adoption rate, especially in the case of indivisible technologies (Feder et al., 1982; Nowak, 1987; Sinden and King, 1990; Barbier and Bishop, 1995; Illukpitiya and Gopalakrishnan, 2004; Lapar and Ehui, 2004).
- Perception of *risk* and *uncertainty* are important, as innovations entail a (subjective) risk. Risk-averse farmers are expected to prefer technologies with short-term benefits (Feder et al., 1982; Marsh, 1998). Those farmers that are willing to take risk and make investments, will adopt a new technology more easily (Sinden and King, 1990; Marra et al., 2003).
- *Labour availability* may influence adoption in either way, as some new technologies are labour saving and others labour demanding (Feder et al., 1982; Nowak, 1987; Barbier and Bishop, 1995).

Institutional factors:

- Integration into *institutional*, *local information*, and *assistance networks* can facilitate the adoption process (Nowak, 1987; Sinden and King, 1990; Marsh, 1998; Baidu-Forson, 1999).
- *Institutional inefficiencies* in the development and delivery of relevant knowledge and assistance are asserted to be a major reason why conservation technologies are not adopted (Nowak, 1987).
- When attitudes are strengthened through *extension and training*, there may be less need for dependence on technical assistance and other net income-enhancing programmes such as cost sharing and tax incentives (Lynne et al., 1988).
- Programmes and institutes should be *flexible* in their approach. SWC programmes should focus more on processes (communication, participation, learning, adaptation and empowerment) rather than being output driven (McDonald and Brown, 2000).
- Empirical studies do not always find a clear relationship between *land tenure* and adoption, but in some cases tenants are less likely to adopt a certain new technology than owners. If tenure is insecure, farmers are unlikely to invest in long-term activities (Gebremedhin and Swinton, 2003; Illukpitiya and Gopalakrishnan, 2004). Some suggest that any observed effect of tenancy may be indirectly caused by the implied relation between tenure and access to credit, markets and technical information (Feder et al., 1982; Nowak, 1987; Lynne et al., 1988).
- *Farm size* can have either a positive or negative effect on adoption, depending on the characteristics of the technology (economies of scale) and the institutional setting (Feder et al., 1982; Nowak, 1987).
- When complementary inputs (e.g. fertilisers or water) are not available, *supply constraints* hinder adoption (Feder et al., 1982).

- The behaviour of *leading farmers* is found to affect farmers' awareness and perceptions (Marsh, 1998).
- Due to *imperfect rural land markets*, the user's costs of soil erosion may not be reflected adequately in, or even bear any relation to, land values. The lack of effective rural credit markets may distort the farming household's decision whether it is worthwhile investing in soil maintenance and its future productivity or exploiting it for immediate gain today. In other words, the opportunity cost of conserving the soil may be extremely high. If the farm household has to borrow in the short-term to invest in conservation, then distorted or non-existent local capital markets may make the direct costs of conservation too high (Barbier, 1995).

It is clear that there exist many constraints that influence adoption behaviour or even impede adoption. Incentives are often used to alleviate these constraints. Section 2.3 will further discuss incentives and how these can influence adoption behaviour.

2.3 The use of incentives for soil and water conservation

There is a clear consensus that SWC practices help to reduce or prevent soil erosion and induce a more sustainable agriculture. However, as discussed in the previous section 2.2, there are many constraints that limit the adoption of these practices. Nowadays governmental programmes and NGO activities are developed in order to raise awareness and to promote SWC in many LDCs. Incentives are used to attract farmers and to overcome the adoption constraints. There is still a discussion going on whether incentives should be used or not to promote soil and water conservation among small-scale farmers in LDCs. There is no special chapter in this thesis dedicated to the analysis of incentives, however, programme incentives will be discussed throughout the thesis and therefore a conceptual framework will be given here.

An incentive is a stimulant that influences the behaviour of an agent. Within natural resource management, an incentive is any inducement on the part of an external agency, meant to allow or motivate the local population, be it collectively or on an individual basis, to adopt new techniques and methods aimed at improving natural resource management (Laman et al., 1996; cited in: Sanders and Cahill, 1999). The aim of natural resource management is to use natural resources in such a way that production is adequate for present needs and that the productive capacity is maintained beyond the present use. Thus, there are two goals: meeting present needs through agricultural production – a short-term and private objective, and conservation of resources – a long-term and social objective. Incentives play a role in 'making private and social objectives meet'. Graaff (1999) calls the private benefits, financial benefits – 'profitability' according to Pagiola (1999) – and the social benefits, economic benefits. When both individual and social objectives are met and a measure is both economic and financial attractive, there is a so-called win-win situation, and no compensation for bearing costs by incentives are needed. However, if measures are economically attractive, but not financially (because of high investment costs or productivity loss), use of incentives for compensation of the costs is justified. These incentives should be the most cost-effective way to bridge the gap between the national economic and private financial profitability. If the individual gains (financial benefits) at the cost of society (economic costs), disincentives like taxes or legislation are more appropriate (Zaal et al., 1998). Figure 2.5 depicts this interaction of financial and economic benefits.

The discussion on the use of incentives in SWC programmes is between those who say that only the win-win situation (both objectives are met) should be aimed at, and those who justify the use of incentives if there are no financial benefits, but the economic benefits for society are sufficiently large.

Economic profitability	Financial profitability: Negative	Financial profitability: Positive
Negative	Not to be executed	Disincentives (regulations)
Positive	Incentives	Win-win situation

Figure 2.5 Use of incentives in natural resource management

2.3.1 The discussion on the use of incentives for soil and water conservation

Agencies promoting SWC practices often make use of incentives in order to stimulate adoption by farm households. Here, the opinions of proponents and opponents of incentives are briefly discussed.

The justification of incentives

SWC incentives of any kind are intended to bring about a measure of equity between the public and private partners who strive to achieve both public and private conservation goals. They are meant to alleviate discrepancies in costs between public objectives and the personal or business objectives of landowners and land managers (Sanders and Cahill, 1999). In some cases, SWC results in benefits not (only) for the land user, but also for society in general. From society's perspective, intervention might be justified when there is considerable off-site damage, or when land productivity is maintained for future generations. However, most SWC practices have to be installed on farmers' fields and the accompanying decisions are taken by the farmers themselves. They are the final decision makers to manage their land in accordance with their objectives, their possibilities and constraints (Lutz et al., 1994a). Furthermore, the farmers are generally those who bear the costs of the implementation of SWC practices. In absence of private benefits for the farmer, there is no incentive or rational for him to invest in SWC, even though there are substantial social benefits (Shiferaw et al., 2003). Therefore, providing incentives to alleviate or compensate additional costs in order to stimulate farmers to adopt SWC practices is justified in terms of the benefits they produce for society and even for future generations. By providing financial incentives these 'externalities are internalised' (Richards, 1999). Moreover, such incentives, either in the form of subsidies or other measures increasing the profitability of SWC, are likely to be continued in order to sustain conservation measures at the socially optimal level (Huszar, 1999). If the farmer is the only beneficiary, use of incentives is often justified by the argument that farmers are too poor to take any risks, while the measures involve heavy investment of labour and money. Therefore, the farmers' income may be reduced in the initial stage of soil conservation (Giger, 1999). Incentives help to compensate this temporary income reduction.

Another justification of the use of incentives is that, since land degradation is often driven by economic incentives, it is necessary to alter these incentives in order to promote conservation goals (Enters, 1999). Resource degradation is encouraged by poor farmers' high discount rates, lack of capital markets, high transport costs, adverse government policies and insecure property rights, in other words, land degradation is (partly) caused by market failures (Antle and Diagana, 2003). In case of imperfect credit markets and insecure property rights, the inter-temporal flow of net benefits from SWC is important for investment decisions. Short-term benefits become more important, but are often negligible. As poor credit-constrained farmers heavily discount long-term benefits in order to meet short-term needs, these negligible short-term benefits work as a disincentive for private investments (Shiferaw et al., 2003). Incentives or programme assistance may then be used to reduce the risk of implementing a new technology, if the innovation is fairly simple but involves a significant initial investment (Nowak, 1987). Another effect of market failures is that prices of agricultural inputs and outputs diverge from their efficient levels, affecting the market incentive for SWC (Eaton, 1996).

Nowak (1987) already warned that SWC programmes will be ineffective if policy makers continue to assume that the adoption of SWC practices is guided solely by economic rationality. Even if SWC practices are profitable for farmers, they might still be reluctant to adopt these because of other constraints. Many authors mentioned the importance of institutional factors within soil conservation which can hamper SWC, like insecure land tenure (e.g.: Lutz et al., 1994a). Also, awareness and knowledge might be lacking. Educational or persuasive programmes can increase the efficiency of existing economic and technical assistance programmes.

The rejection of incentives

Many authors have argued against incentives, as many examples are known where incentives induced changes in land use on the short-term, but farm households returned to their old land use practices as soon as these incentives were withdrawn. They were only interested in the incentive itself (e.g. food, cash, agricultural equipment), and not in the accompanying technology (Bunch, 1999; Sanders and Cahill, 1999). Bunch (1999) gives more reasons why direct incentives do not work: payment for the construction of SWC practices make farmers think that, as the programme or government had such an interest in these practices, they should also pay for the maintenance. Besides that, a paternalistic dependency is created: the farmer thinks he is unable to implement these practices without external help. Also, he is not motivated to experiment with and adapt the practice to his own circumstances, as he will not get the payment then. Programmes also use incentives to achieve quick results, without paying much time- and energy-consuming attention to sustainable effect of the programme. It is even argued that weak SWC programmes are more likely to use incentives to achieve its unsustainable goals. Often the root causes of the problem of land degradation are not addressed in a SWC programme (Giger, 1999). Furthermore, the incentives influence the strategic behaviour and attitude of the beneficiaries.

In an ideal situation the SWC practice should be an incentive in itself. SWC practices should conserve soil and provide productive benefits to the farmer, like biological (or vegetative) conservation techniques (Stocking and Tengberg, 1999). SWC practices should no longer be seen as goals on its own, but incorporated in the overall farming system and farmers' economic strategies. Instead of discussing the effectiveness of direct incentives for soil conservation, the issues should be put in a broader environment and socio-economic context. There must be a clear understanding of the rural economy, changing livelihood strategies and the evolving farmers' perspectives (Malla, 1999). According to Bunch (1999) the incentives needed for a successful SWC programme are motivating the farmers to innovate and create opportunities for these innovation processes.

2.3.2 Types of incentives

A part of the discussion is caused by the fact that different definitions of incentives are used. Table 2.2 gives a brief overview of different types of incentives as they are used within conservation programmes. Note that those arguing against incentives are mainly arguing against direct incentives used by programmes. Indeed, direct incentives are often misused, as well by the transmitter (the programme), as by the receiver (the beneficiary, often the farmer). Direct incentives are designed to have an immediate impact on individual and community behaviour and can be either in the form of cash or kind (Zaal et al., 1998). Direct incentives have a discriminating effect: only adopters benefit from these incentives, whereas indirect incentives affect the whole community or population whether they adopt the new technology or not. Most agencies use direct incentives to motivate farm households to change their land use. These incentives will be called programme incentives throughout this thesis.

Table 2.2 *Classification of incentives used in conservation programmes*

Incentives				
Direct incentives	***Indirect incentives***			
	Regulating incentives	***Enabling incentives (or social instruments)***	***Variable incentives***	
			Sectoral incentives	***Macro-economic incentives***
Cash payment Subsidies Agricultural implements Food aid Rewards and prizes Subsidised credit	Fines Taxes Law	Land security Market development Decentralisation of decision-making Credit facilities National security	Input and output prices Subsidies Tariffs	Exchange rate Interest rates Fiscal and monetary measures

Adapted from Sanders and Cahill (1999) and Enters (1999)

Regulating incentives can be regulatory measures like legal and institutional arrangements (Graaff, 1999) or legislative and administrative instruments like restrictions and regulations (Enters, 1999). Laws are sometimes constructed to prevent natural resource degradation and violation of these laws is punished with fines. These incentives are especially used for nature reserves and protection of forests. Often farm households are restrained because of market failures and insecurity. Incentives like land security, credit facilities and market development can nullify or diminish these constraints and enable technology adoption. Furthermore, enabling incentives mediate the farm household's potential response to the variable incentives (Enters, 1999). Another type of enabling incentives are social instruments that are used to raise awareness or moral persuasion through extension efforts

(Graaff, 1999). Variable incentives alter the net returns that farm households receive from their SWC activities, and can be applied directly through subsidies or cheap credit, or indirectly through fiscal market-based instruments. Market-based instruments use the 'beneficiary pays' approach in case of SWC, and are based on the concept that 'external' beneficiaries (the society, future generations or downstream residents) should compensate the land users for the benefits provided. The main principal is that these market-based instruments internalise social costs and benefits into private returns. This fiscal mechanism can be either executed through taxes or through subsidies (Richards, 1999). Temporary or permanent price policies are also financial incentives which can increase or decrease returns of investments (Enters, 1999).

Incentives are often used to achieve a wide-scale implementation of conservation practices, but in order to be effective they should be oriented towards the land users' problems (Sanders and Cahill, 1999). If a misconceived incentive is used that does not correspond with the existing problem, the intended objective will not be reached. Therefore, it is important to know why a deteriorating situation persists. Instead of trying to find the most appropriate incentive to stimulate change it may be far more effective to find the disincentives that bring about a disabling environment (Enters, 1999). To be economically viable and socially acceptable, incentive systems should be effective (results in line with their purposes), efficient (costs not exceeding social gains) and also equitable (all participants agreeing on fair compensation) (Graaff, 1999). Incentives should be related to 'farmer pull' instead of 'technology push' (Graaff, 1993). The government's role should change to a facilitator with the main objectives of setting the right conditions or creating an enabling environment for technological change. These new policy instruments should be market-based and at the forefront of any programme incentives.

2.4 Concluding remarks

As soil erosion consists of several processes affecting the soil (section 2.1), physical and economic assessment of soil erosion and SWC is complicated. However, by focussing on soil productivity and crop production, a simpler approach is proposed ignoring the complexity of soil erosion processes. In this thesis only the effect on soil productivity and crop production will be considered, as this is the main concern of most farm households. Since this thesis focuses on the behaviour of farm households, on-site effects of SWC are considered, ignoring possible off-site effects. It is assumed that these possible off-site effects do not affect farmers' decision-making and behaviour. The analyses described in this thesis are based on the 'change in productivity approach' (Chapter 5).

The evaluation school and the adoption school are the two main schools of economic analysis of SWC. In this thesis, approaches of both schools are applied. The most common approach within the evaluation school to determine the profitability of SWC practices is cost-benefit analysis (Chapter 6). As profitability does not automatically result in adoption, analysis of adoption behaviour of farm households is important to determine other constraints to adoption. The analysis in this thesis (Chapter 7) is based on the adopter perception paradigm.

Despite extensive research on technology adoption among small-scale farmers, and despite the discussion on the use of incentives, little empirical research is done to analyse the effect of incentives on the adoption process. Most knowledge is based on evaluation reports of programmes that used these incentives to induce adoption. To avoid confusion about incentives, several types of incentives were defined in section 2.3. Most programmes promoting SWC practices make use of direct incentives to stimulate adoption, but these can be accompanied with enabling incentives. The discussion on the use of incentives is partly caused by different definitions and understanding of incentives.

Chapter 3

Setting the stage

3 Setting the stage

The research described in this thesis took place in the Peruvian Andes. The environment, history and socio-economic development of Peru are quite different from other regions in the world. Therefore, in this chapter a description is given of the bio-physical, historical, socio-economic and institutional context in order to be able to put the research results in the right perspective.

3.1 The bio-physical context of the Peruvian Andes

Few countries have such a high variety in geography, ecology, climate and biodiversity as Peru (Heredia, 1997). In a thousand metre of mountainside of the Andes, more biological and topographical diversity can be found than in a thousand kilometres of flatland, resulting in many neighbouring micro-niches (Rhoades, 1986). This heterogeneity creates both opportunities and limitations to development (Crissman and Espinosa, 1996).

3.1.1 The Andes

The Andes is the longest mountain chain in the world with a length of 7.200 km (Tapia, 1996). The Andes emerged by subduction of the South American plate and the Nazca plate beneath the Pacific Ocean. The final uplifting occurred in the tertiary period, thus the mountains are relatively young and have still immature soils (Becker, 1988). The Peruvian Andes is referred to as the central Andes and is located at 12 to 18 degrees south latitude (Winterhalder, 1993). The Andes mountain range covers 24% of the Peruvian territory (Gonzales de Olarte, 1986).

The Peruvian Andes have four characteristics that affect the development (Tapia, 1996):
- *Inaccessibility*: Due to the location, altitude, slope and physical conditions, the access to and within the Andean region is difficult. Isolation, lack of communication, and limited mobility are all results of the inaccessibility.
- *Fragility*: Areas with the steep slopes and light soil formations are susceptible to degradation. Inadequate use, overexploitation and sudden changes make the natural resources even more vulnerable. Also the economic structures (e.g. markets, access to credit) can be considered fragile. Fragility is related to marginality.
- *Marginality*: The region does not benefit of investments in productive activities because of its isolation and remoteness. The population receives no priority in national development plans.
- *Diversity*: The heterogeneity caused by altitude, pedological and geological conditions, and the location between the tropics result in many diverse ecological zones and a huge biodiversity of plants and animals. This diversity can be an advantage if good use is made of the complementary properties of the different zones.

Climate

In the Andes the weather is as important for agricultural production as the soil and inputs (seeds and labour). The central Andes form a massive barrier for the humid air coming from the Atlantic Ocean and Amazon Basin, that form into rain clouds when it ascends the eastern escarpments of the Andes (Winterhalder, 1993). Annual rainfall diminishes from north to south and from east to west in the Andes, but increases with altitude (Tapia, 1996). The rainy season endures from October till

March, when the air humidity and wind increase (Winterhalder, 1993). There exists an inter-annual climate variability causing dry or wet periods every few years due to temperature differences of the ocean along the Peruvian coast. This phenomenon is known as El Niño Southern Oscillation (ENSO), or more popular 'El Niño'. This event occurs once every three to six years. During an El Niño episode, rainfall dramatically increases in some areas, whereas droughts occur in other regions. The next phase, known as 'La Niña', produces roughly the opposite climate patterns (Holmgren et al., 2001). The amount of annual rainfall is thus highly variable, in time and space. This erratic rainfall pattern makes the weather conditions in the Andes unpredictable and as a consequence the farmers vulnerable. Even if it is known that there will be an El Niño year, it is still not possible to predict the severity of the event and its influence on the agricultural production.

Temperature hardly varies among seasons, but more so between day and night, especially at higher altitudes. During the dry season diurnal temperature fluctuations are high, as the temperature depends more on the (lack of) cloud cover than on changes in solar radiation due to the tropical latitude of the central Andes (Winterhalder, 1993). Temperature also varies by altitude with an average decrease of 5.5°C per 1000 meters increasing altitude (Johnson, 1976; Winterhalder, 1993).

Agro-ecological zones

Due to its diverse topographic and climatic conditions, the Andes contain a large variety of ecological conditions: from tropical to temperate, from humid to arid, from glaciers to hot valleys. This ecological heterogeneity determined the development of different agricultural systems, ranging from fallow systems to permanent cropping systems and from intensive to very extensive livestock production systems (Bernet, 1995). Taking advantage of this diversity along altitude, agriculture in the Andes has been dominated by the strategy of maximum diversification along altitude, which is also called the 'vertical control' of the mountain slopes (Murra, 1975; Morlon et al., 1982; Chonchol, 1995). The interaction among the different agro-ecological zones is necessary, because none is self-sufficient. The variety of agro-ecological zones along the slope creates opportunities but also limitations for agriculture. It might be desirable to cultivate a cover crop on a certain location in order to reduce soil erosion, but this might be impossible due to frost or drought. The other way around, crops suitable for a given climate might not be suitable for the given soil (Crissman and Espinosa, 1996).

In Peru, eight different major natural regions can be distinguished, of which five are located in the Andes (see Table 3.1). The main agro-ecological zones in the Andes are *Quechua*, *Suni* and *Puna*. Below, descriptions are given of these three zones (Morlon, 1996; Pulgar-Vidal, 1996):

- *Quechua*: due to its pleasant temperate climate and the suitability of the soils for agriculture, this zone has been intensely occupied and densely inhabited since ages. The annual maximum temperature varies between 22 and 29°C; and the minimum between 4 and 7°C. Annual rainfall ranges from 400 to 1000 mm y^{-1}, depending on the longitude and latitude. The seasonal rains are of regular intensity, but sometimes destructive rainstorms occur. The frost line is found in the higher parts of this region at about 3000 m.a.s.l.[1] during winter (May to August). As the frost affects the crops, this period is dedicated to harvest and fallow activities. Only on protected places with access to irrigation, crops are sown during this period, taking advantage of the fact

[1] m.a.s.l. = meters above sea level

that the frost mainly affects plain land and less the sloping land. Maize (*Zea mays*) is the basic food crop and different varieties are grown. In order to increase the maize production, irrigation structures and terraces have been developed in this zone long time ago. Other important crops are bean (*Vicia fava*), potato (*Solanum tuberosum*), vegetables and fruit trees. Reforestation with eucalyptuses (*Eucalyptus globulus*) is taking place since last century.

- *Suni*: this zone (also called *Jalca*) is characterised by steep slopes, deep gorges and rock formations. The climate is cold and dry due to the elevation and the local winds. The annual mean temperature fluctuates between 7 and 10°C, with a maximum at 20°C and a minimum between -1 and -16°C. The soil is hot as it receives the direct rays of the sun but it cools down quickly once the sun sets. Average rainfall is about 800 mm y^{-1}. The main crops cultivated in this zone are typical Andean crops like: mashua (*Tropaeolum tuberosum*), quinoa (*Chenopodium quinoa*), tarhui (*Lupinus mutabilis*), bean (*Vicia fava*), potato (*Solanum tuberosum*), oca (*Oxalis tuberosa*) and olluco (*Ullucus tuberosus*). Because of the remoteness, the unfavourable conditions for agriculture and the degraded pastures, many inhabitants of the *Suni* emigrate nowadays towards lower regions with off-farm employment opportunities and education possibilities for the children.
- *Puna*: the vegetation of the *Puna* is scarce but nutritious. This zone is the natural habitat of the Peruvian camels: llama (*Lama glama*), alpaca (*Lama glama pacos*), vicuña (*Vicugna vicugna*) and guanaco (*Lama guanicoe*). Potato (*Solanum tuberosum*) is cultivated as food crop. Annual rainfall ranges from 150 (dry *Puna*) to more than 1000 mm y^{-1} (humid *Puna*). At night, temperatures drop below zero.

Table 3.1 *Agro-ecological zones in Peru (after: Pulgar-Vidal, 1996)*

Agro-ecological zones	Altitude (m.a.s.l.)	Climate	Main activities	Agricultural products
Coast	0-500	Temperate to warm, 0-50 mm y^{-1}, high humidity	Industry, fishery, high-input commercial agriculture, urban areas	Coconut, palm tree, olives, grapevine
Yunga (Andes)	500-2300	Sub-tropical, 400-1000 mm y^{-1}	Fruit trees	Avocado, citrus, sugarcane
Quechua (Andes)	2300-3500	Temperate, spatial variability rainfall	Small-scale agriculture, horticulture, livestock	Maize, wheat, beans, fruit trees
Suni (Andes)	3500-4000	Cold, spatial variability rainfall	Small-scale agriculture, livestock	Potato, mashua, quinua, oca, olluco
Puna (Andes)	4000-4800	Very cold, 200-1000 mm y^{-1}	Livestock breeding: llamas, alpacas	Potato, barley
Cordillera (Andes)	4800-6768	Glacial	Mining	
Higher jungle (Amazon)	400-1000	Very warm and humid, >3000 mm y^{-1}	Rain forest, agriculture, coca	Rubber, oil palm,
Lower jungle (Amazon)	80-400	Hot and humid, 2000-3000 mm y^{-1}	Rain forest, fishery, shifting cultivation	Chestnut, natural vegetation

3.1.2 History of agriculture in the Andes

Ancient times

It is assumed that around 40,000 BC the first people, hunters, came from Asia towards the Americas (Chonchol, 1995). Prehistoric hunters and gatherers preferred mountains because of the great plant and animal diversity within short distances, a year-round supply of water, wood, and shelter, and favourable conditions for self-defence (Rhoades, 1986). Tuber crops, like potato, were important in the Andes. Maize was more important in the warmer zones at lower elevations (Burga and Manrique, 1990). Around 1000 BC the first permanent settlements arose in the Peruvian Andes, with their accompanying social structure and rules (Chonchol, 1995).

Agricultural terraces are among the most distinctive features of the Andean landscape. In the pre-Hispanic era, terraces built by indigenous societies supported large populations. It is estimated that nowadays the ancient terraces total up to 500,000 ha, and that up to 75% of these terraces are now abandoned and crumbling (Treacy, 1998). Terrace-building developed gradually. With an increasing agricultural population in steep, rocky valleys, the building of terraces may have appeared simply an effective way of clearing the land by piling up the stones and leaving the largest area as tillable land (Cook, 1916). By AD 300 agricultural terraces (*andenes*) were widely used. The construction of these *andenes* for agriculture continued to develop over almost all the Andes, reaching its highest point during the Inca Empire, just before the Spanish conquest (Mujica, 1995).

Inca Empire

Between AD 1250 and AD 1532, the Inca Empire was established. The Incas improved the terracing and irrigation techniques. Thanks to the development of a hierarchical political system, compelled taxes in the form of labour supply (*mitas*), extended infrastructure and food storage, the Incas were able to dominate large regions. Starting from 1440, the Incas expanded their area, conquering other tribes and disseminating their culture and agricultural techniques throughout the western part of South America. Social organisation was an important factor in enabling the Incas to accomplish what they did in agriculture (Cook, 1916). The Inca society was characterised by a strong hierarchy and an efficient planning (Araujo, 1986). The aim of agriculture was not maximising yields, but sustainable management. The needs of the society were optimised within the absolute borders of the ecosystem (Rist and Martin, 1991). The agricultural land was divided in three categories: 1) land used for religious purposes, with mostly maize production for ceremonial rituals; 2) land for the state, destined for food production for the state; 3) land for the communities and its inhabitants for private food production (Chonchol, 1995).

The Incas organized terracing as part of a systematic and nationwide policy of land improvement and colonisation (Donkin, 1979). The prime objective of terrace-building was to expand maize cultivation wherever possible, in association with irrigation. Above the normal altitude limit of maize (3200 – 3500m) rainfed terraces were presumably used for the staple food crops – tubers and cereals (Mujica, 1995). The ultimate benefits were higher, more concentrated and less fluctuating yields, but there is hardly any evidence suggesting that terraces were constructed to prevent soil erosion. Terraces enabled irrigation on slopes and the consequently extension of agriculture into climatically marginal areas. Relatively steep terraced sites had the advantage of a fuller solar exposure. Crops on terraces receive more sun than they would if they were planted as densely on a flat field. The terraced slope also receives a more equal distribution of airflow, and the turbulence of warm air reduces the risk of frost. Terraces allowed water systems to function with little human effort, relying on gravity and a sophisticated engineering system. Besides, on sloping fields there were no dangers of flooding and sedimentation like in the valley bottoms. It was probably easier to construct irrigation structures and terraces on slopes than to develop a good drainage system to cultivate in the valleys. Furthermore, rural settlements were situated on hill tops for defence reasons, and fields that were immediately adjacent were easier to protect and cultivate (Donkin, 1979; Mujica, 1995).

Spanish conquest

In 1532, the Spanish conquered South America, and the indigenous civilization (the Inca Empire) collapsed in the following years. The Spanish arranged alliances with the indigenous elite, the former Inca rulers, which accelerated the diffusion of European customs and traditions (Burga and Manrique, 1990), and changed agriculture drastically. The Spanish introduced new crops (wheat, barley, vegetables), animals (sheep, cattle, horses and donkeys) and also new practices like the plough and animal traction. In order to make efficient use of animal traction, the Spanish cultivated only the gentle slopes in the valley bottoms, abandoning the ancient terraces and the indigenous system of vertical control (Rist and Martin, 1991). The Spanish had much interest in mining activities in the mountains, and agriculture was more and more neglected (Tapia, 1993). Meanwhile, the mining industry became the trigger of the economy. New urban centres emerged, and money, markets, as well as private property were introduced (Burga and Manrique, 1990).

The Spanish applied extensive agriculture and productivity decreased while irreversible soil erosion processes started (Rist and Martin, 1991). *Haciendas* appeared in order to meet the demand for food crops on the emerging markets of the urban and mining centres, and the European demand for tropical products, like coffee, cocoa, sugar cane and cotton (Chonchol, 1995). Most *haciendas* were situated near the urban centres at the coast (Cotlear, 1989). As land was abundant and labour became scarce due to a population decrease and the expanding labour-demanding mining industry, livestock keeping and dairy production became increasingly important in the Andes (Burga and Manrique, 1990). The *hacienda* was based on the Spanish social agricultural systems, consisting of large land property and fixed workforce living on the estate. Agricultural land, including its inhabitants, was redistributed. Land that the Incas used for religious purposes was given to the Catholic Church and the land of the Inca state to the Spanish Crown (Chonchol, 1995). The Spanish relocated the indigenous population in peasant communities in the 16th century, officially to protect Indian rights, but also to make more efficient use of their (decreasing) labour force and to Christianise them. First, the communities had to pay taxes, but later many had to deliver labour to the nearby *haciendas* instead (Cotlear, 1989).

Republic of Peru

Once the independent Republic of Peru was established in 1825, more attention was paid to the agricultural development (Tapia, 1993). Export of primary agricultural products, like sugar, cotton and wool, became more important (Burga and Manrique, 1990). Especially *haciendas* with sheep and cattle farming in the Andes expanded due to the increasing international demand for animal products, mainly wool (Tapia, 1994).

Agrarian Reform

After a military revolution in 1968, an agrarian reform was proposed in order to redistribute land and modernise the agricultural sector. Another important objective was to defeat the capitalist elite by introducing co-operatives and direct state interference. The Agrarian Reform in Peru started in 1969 and ended in 1978. Before the reform the haciendas controlled about 75% of the land, whereas the indigenous rural population had access to only 15% of the land of low quality. Agricultural production stagnated and food demands were exceeding the production, leading to extreme poverty of the rural population. In the Andes, land of the *haciendas* was returned to the peasant communities (Sheahan, 2001). Though the indigenous people recovered the land, the territory of each peasant community was not distributed along altitude anymore like in ancient times. This disrupted the 'vertical control' strategy (Morlon, 1996).

The agrarian reform resulted in a new structure with three types of exploitation (Chonchol, 1995):

- collective property of production units with strong state intervention;
- private property with small commercial farms (often former *hacienda* owners);
- subsistence farming by a majority of small-scale farmers, who were either independent or member of a peasant community.

The majority of the farm households in (the southern part of) the Peruvian Andes belong to the third type of exploitation. This thesis will therefore focus on this type of farming system. However, these small-scale farm households are not self-sufficient anymore, so mere subsistence farming is rare.

3.1.3 Contemporary agriculture in the Peruvian Andes

Contemporary small-scale agriculture in the Peruvian Andes is a mix of indigenous knowledge and customs, and exogenous (European) crops, animals and tools. Agriculture is most affected by the climatic risks (e.g. El Niño, drought or frost) and plagues. However, farm households in the Peruvian Andes have limited disposal of formal mechanisms to reduce risk, like access to credit or insurances (Escobal and Agüero, 1997). Therefore, farm households diversify their farming activities the same way they diversify their livelihood (section 3.2) in order to reduce risk.

Crop cultivation and risk

Small-scale farm households apply a risk-spreading strategy within crop cultivation: crops are sown in fields at different ecological zones with different micro-climates, sowing is spread over time, and various varieties with different climatic resistance are cultivated. The specific characteristics of each crop in relation to frost resistance and growing period determine the cultivation altitude of each crop. A hundred meter difference in altitude shortens the growing period by two weeks (Bernet, 1995). As maize is the most delicate, this crop always receives priority and is cultivated in the lowest areas, even though potato and other tuber crops have higher yields in these zones. When new crops are introduced, these are sown in the lower areas, while the 'regular' crops are moved upwards the slope (Mayer, 2004). The most important determinant of the cropping pattern is the consumption demand of the household, and not profit maximisation.

Livestock

Livestock comprises a crucial component in the diversification of agricultural production and farmers' income in the Andes. Farmers keep different animals in order to diversify animal production (meat, wool, dung, milk) and other benefits (working power, savings). The oxen plough is nowadays a common technology. Sheep, introduced by the Spanish besides cattle, became more important than the domestic camels: llama and alpaca. In rougher and higher zones, where water availability and fodder quality limit sheep keeping, llamas and alpacas still dominate. Sheep are important producers of meat, wool and dung, but also serve for the exchange of goods or services. Wool is transformed locally into handicraft goods. Animal feeding depends on the available fodder in a community, which consists mainly of communal pastures and crop residues. As fodder is scarce during the dry season, fodder crops like barley and alfalfa are grown for cattle. Most of the activities concerning livestock husbandry are undertaken by women and children, while men are in charge of the labour-intensive crops (Bernet, 1995).

Reciprocity: exchange of labour

Reciprocity is an important principle in Andean society. The reciprocity becomes most visible in the mutual help with labour-demanding activities. These reciprocal labour exchanges are very important to overcome labour shortages, especially during the harvest season. There are different types of reciprocal assistance:

- *Ayni*: reciprocal exchange of goods and services, mainly labour, between households (Rist and Martin, 1991).
- *Minka*: labour in exchange for food, goods or money (Rist and Martin, 1991).
- *Faena*: each household belonging to the community is obliged to deliver labour for community purposes (Bernet, 1995), like improvement of roads, cleaning of irrigation structures, construction of a school (Gonzales de Olarte, 1986). These activities are normally carried out during the dry season when the agricultural activities are less labour-demanding.

Land tenure in peasant communities

One can distinguish two types of small-scale farm households in the Andes: farm households belonging to a peasant community (*comunidad campesa*), and the individual farm households (Gonzales de Olarte, 1994). Individual farm households who do not belong to a registered peasant community, have private ownership over their land (Figueroa, 1989). But the majority of the small-scale farm households in the central and southern Andes are member of a peasant community (see section 3.2.3 for further discussion). Farm households that are member of a peasant community do not have private land property rights, and cannot sell or buy land. Instead, each family has users' rights for certain pieces of land. This user right is passed on to the children.

Two main types of user rights exist: the temporal user right (*aynoka*) for land that is managed by the community and the permanent user right (*sayaña*) for land that is privately managed. The *sayaña* land with permanent user right is often located near to the houses. These fields are intensively cultivated by the farm household (with use of fertilisers, irrigation, et cetera). The crops grown are important for home-consumption and for market sales (Bernet, 1995). The communal *aynoka* land is, in general, rainfed marginal land situated at the upper slopes of the community territory. This land is managed by means of a specific Andean fallow and rotation system, the so-called sectoral fallow system (Figure 3.1). The rotation has to be collective in order to keep the animals outside the land under cultivation (Figueroa, 1989). The communal land is divided into a certain number of sectors corresponding to the number of years of fallow the soil needs to rehabilitate (varying between 6 to 10 years). However, these fallow periods are shorter nowadays due to the increased land pressure. The community decides collectively on the fallow period and crop rotation for each sector. Each household owns several plots in each sector. During the cultivation period, land use rights to these fields belong to the farm households who cultivate them. Farmers tend to cultivate these fields extensively, as the crops in the *aynokas* are much more exposed to climatic risks. Another problem is that harvests in *aynoka* fields are more likely to be stolen. During the fallow period the temporary property rights are transferred to the community. *Aynokas* under fallow are used as pasture, and all community members have equal rights to pasture their animals on these fallow *aynokas* (Bernet, 1995). The *aynoka* system is still of importance in the central and southern part of the Peruvian Andes. In the north, however, this system disappeared long time ago (Tapia, 1994).

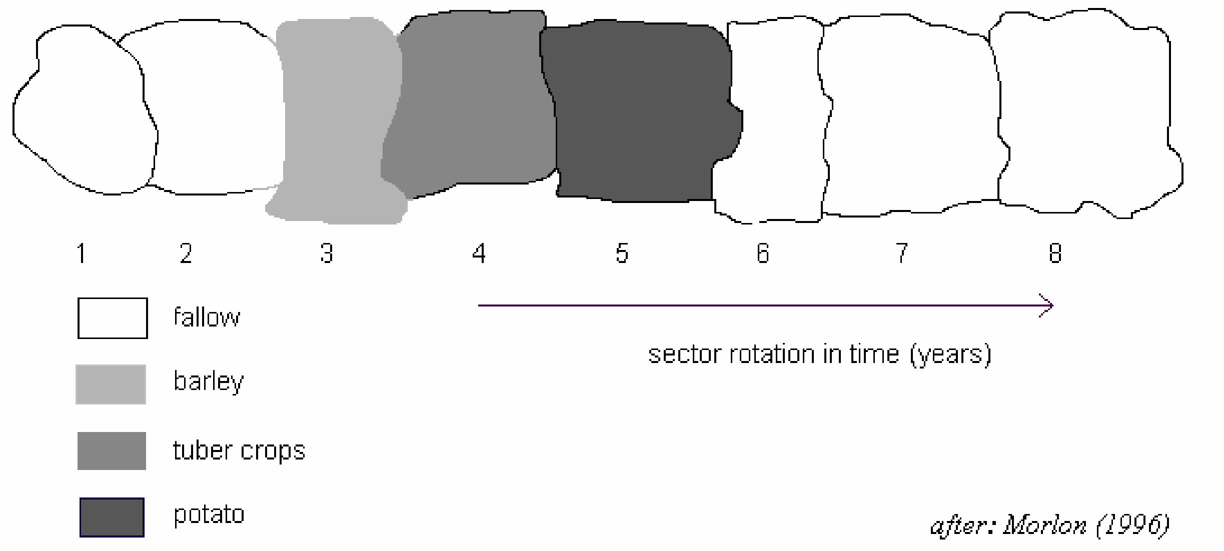

Figure 3.1 Communal sector rotation (*aynoka*) in time

Farm households thus have several fields scattered across the community. The fragmentation of the land is caused by ecological, economic and demographic factors. Scattered fields reduce the risk of total crop failure and increase the possibility to cultivate different crops (Mayer, 2004). The distribution of fields makes sure all families have access to soil types of different quality and at different agro-ecological zones. Furthermore, it spreads labour demands over the season, as crops are planted and ripen according to altitude (Rhoades, 1986). When the parents die or 'retire', the land is divided among all children of the family. Each gets a part of the different fields that have different qualities and different agro-ecological conditions (Figueroa, 1989). In order to achieve a fair division of land, the fields get more and more fragmented.

Irrigation

Irrigation has a long history in the Andes and contributed to the development of, among others, the Inca Empire. However, nowadays large parts of the impressive irrigation infrastructures of the Incas are abandoned (Gelles, 2000). Rivers, creeks, springs and lakes constitute the sources of water supply for irrigation. Water is directed from canals towards the fields making use of gravity, and water is applied on the fields through surface irrigation. The physical (canals, wells, et cetera) as well as the social (people responsible for supply and division) infrastructure is organized at community level. The construction and maintenance of the irrigation infrastructure is regulated by the community, making use of *faena*. The community assembly chooses the men responsible for the irrigation structures and division of water (Gonzales de Olarte, 1986).

Erosion in the Andes

Throughout the Andes soil erosion and land degradation are considered to be among the most serious environmental problems (Byers, 1990). It is assumed that 57% of the land in the Andes is affected by moderate to severe erosion (Felipe-Morales, 1993a). Land use is the determining factor of soil erosion (Harden, 1993), with roads and cultivated steep slopes as main contributors. Lack of vegetation cover is the most important, and the slope the second most important factor causing soil erosion (Harden, 1988). Overland flow producing areas (like roads an bare fields) often cause rill erosion down-slope (Harden, 1992).

Table 3.2 *Estimated soil erosion rates for Andes regions in Peru and Ecuador*

Authors	Conditions (rainfall, slope)	Experiment	Treatment	Erosion (Mg ha^{-1} yr^{-1})
(Felipe-Morales, 1993b)	500-750 mm Slope: 25%	Runoff plots, 40 m^2	Maize, up-down ploughing	20.0
			Maize-potato-oat rotation, up-down ploughing	14.2
			Maize-potato-oat rotation, contour ploughing	6.9
			Maize-potato-oat rotation, mulching	3.7
(Low, 1967)		Simulation, USLE	Peru	0 – 70
			Southern Andes	10 – 30
(Pastor, 1992)	1050 mm Slope: 30-60%	Runoff plots, 40 m^2	Natural vegetation	0.4 – 1.1
			Sweet potato, contour ploughing	0.6 – 1.4
			Sweet potato, up-down ploughing	1.8 – 4.0
			Clean fallow (bare)	3.1 – 14.9
(Torre, 1985)	2000 mm Slope: 20%		Maize – pea rotation	4 – 45
			Pea – cassava rotation	12 – 70
(Alegre and Rao, 1996)	2200 mm Slope: 15-20%	Runoff plots, 150 m^2	Bare soil	141
			Annual crops (rice – cowpea)	79
			Contour hedgerow cropping	6
(Byers, 1990)		Rainfall simulations	Maize	82
(Harden, 1988)	800-1400 mm Slope: >50%	Rainfall simulation	Thin dusty soils	20
			High-altitude, organic matter rich soils	40
			Intermediate elevation, dark Andean soils	80

Only a few attempts have been made to quantify soil erosion in the Andes (Table 3.2). Estimates of soil erosion rates in the Peruvian Andes vary between 0 and 140 Mg ha^{-1} y^{-1}. However, in many studies most erosion occurred only during one or two rainfall events (Crissman and Espinosa, 1996). The empirical results are time- and site-specific, and cannot easily be extrapolated to other regions, as there is a risk to overestimate the erosion problem. On the other hand, most studies do not include potential upslope runoff sources, and erosion caused by runoff water might be underestimated (Harden, 1992). Even though the exact quantity of erosion is not known, SWC still seems to be indispensable for a sustainable agriculture on the steep slopes. As soil is a production factor and a major asset for the Andean farmer (Crissman and Espinosa, 1996) it is important to maintain and improve it. However, hardly any research has been done in Peru to measure the effect of SWC practices on soil erosion and crop yield. According to Felipe-Morales (1993a) a positive effect of SWC practices on crop production is obtained due to soil conservation, but also to water conservation.

SWC interventions in Peru

As said before, Peru has a long history in terracing. Main purpose of the terraces in ancient times was the facilitation of agriculture on steep slopes and the modification of the micro-climate (enabling irrigation and reducing the risk of frost) in order to create favourable conditions for crops like maize (Cook, 1916; Mujica, 1995). In some regions these ancient terraces are still used. But abandonment is almost total on non-irrigated terraces. The irregular rainfall regime makes labour and seed investment too risky for the low crop prices obtained, so land use has changed to livestock keeping, promoting erosion and collapse of walls because of the cattle and sheep grazing on the terraces. Furthermore, there is a shortage of labour that is needed for long-term soil conservation practices like terracing (Inbar and Llerena, 2000).

Attempts have been made to rehabilitate ancient terraces, but programmes failed, as the original characteristics of the material used, workmanship, or design were not considered. In case the traditional social organisation of the Andean communities and the socio-economic principles of reciprocity and redistribution were used, terraces have been maintained and continue to be used even after the restoration programme ended. Communal participation is a must in any programme related with recovery of traditional technologies (Mujica, 1995). Another factor frustrating the rehabilitation is that there has been a shift of focus in the Andean economy from crop production as main activity to one of many survival strategies of small farm households over the past century. Also, communities are now more fragmented and heterogeneous, with weakened traditional authorities and abandoned traditional systems of land management (Rodríguez and Nickalls, 2002).

Since the early 1980s, NGO's and governmental institutions in Peru became more and more interested in SWC to prevent soil erosion (Alfaro, 1988). The governmental programme PRONAMACHCS (Programa Nacional de Manejo de Cuencas Hidrográficas y de Conservación de Suelos) has been the most important promoter of SWC activities in the last two decades. The main SWC practices that are promoted by the various programmes are: slow-forming terraces, bench terraces, infiltration ditches, rehabilitation of ancient terraces and reforestation.

Various experiences of NGO's and governmental programmes have shown that SWC interventions are most successful when it enables the cultivation of an important crop for the local economy (Agreda, 2000a; Rodríguez and Nickalls, 2002). Combination of terraces with irrigation is desirable, as this enables two crops a year. A package containing a diversity of technologies is also desirable (Winters et al., 1998). As farm households and agricultural systems are diverse there exists no 'one solution fits all' practice. A technology package offers farm households the possibility to choose those practices that fit their farming system most. The promotion of SWC practices together with measures that enhance short-term profitability of agriculture increases the probability of a successful adoption (Winters et al., 2004).

Most programmes use direct incentives to stimulate adoption. Frequently used incentives are goods in kind (Winters et al., 1998; Agreda, 2000b) and more recently the organisation of farmer competitions (IIDA, 2001; Kessler, submitted). An advantage of these competitions is that during the evaluations, farmers learn from each other during the informal discussions (Valverde and Sotomayor, 2003). Strengthening of the social organisation and the local economy seem to be prerequisites for a successful SWC intervention (Kessler, submitted). Incentives can stimulate adoption of SWC but have to be provided carefully (Winters et al., 1998; Agreda, 2000b).

3.2 Economic development in Peru

In order to understand the peasant economy and poverty in Peru, one has to understand the economic history. In this section, the national economy and the process of the marginalisation of the peasant economy are explained.

3.2.1 Explaining inequality and poverty in a nutshell

Peru is characterised as a lower middle-income country by the World Bank (2004a), but is dealing with high levels of poverty and inequality. Poverty and inequality in Peru have three main causes: demographic changes, geographic conditions, and economic policies (Gonzales de Olarte, 1997).

Demographic changes

After the Spanish conquest, the indigenous population decreased from about 8 to 1.3 million within 70 years due to violence and European diseases, like the flue, smallpox, and measles (Wachtel, 1971; Morlon, 1996). In the coastal region, the indigenous population disappeared almost completely, and was replaced by Europeans and slaves from Africa. In the 19th century, death rates decreased due to improved health services, resulting in a population growth (Cotlear, 1989). In 2005, the population is estimated at almost 28 million, with a current growth rate of 1.5% (INEI, 2005).

The urban population grew more rapidly than the rural population in the last four decades, due to the migration from rural towards urban areas (Gonzales de Olarte, 1994). The reason for this mass migration was the industrial expansion in the 1960s in the urban areas, especially at the coast. However, in the period 1975-1990 Peru suffered a severe economic crisis, leaving many people in the urban areas without sources of income, inducing urban poverty (Gonzales de Olarte, 1997). In 2002, the rural population still constituted 28% of the total population (INEI, 2005). Despite the migration towards the urban areas, the absolute number of people living in rural areas still increases, resulting in an increased pressure on the natural resources. As a consequence, agricultural production decreased while the poverty increased in the rural areas, especially during the violent period in the 1980s (Gonzales de Olarte, 1997).

Geographic conditions

In Peru, the land suitable for agriculture is limited and dispersed, as the major part is either arid, has steep slopes, or is covered under rain forest. The land available per active labour force is low compared to other South-American countries. In 1994, land per labour force was 1.46 ha in Peru in comparison with 3.74 ha for South America as a whole (Sheahan, 2001). Due to bad access to markets, climatic risks, and low productivity of the soils in the Andes, most farm households produce only for home consumption. Escobal and Torero (2000) show that the most important cause of differences in wealth between the coast and the Andes is the difference in infrastructure and private assets like education, farming experience and household size. The inferior infrastructure in the highlands, in turn, is closely related to the geography.

Changes in economic policies

Until the 1940s, Peru's most productive sector was agriculture. After the Second World War, when there was an increasing demand for minerals (like copper, zinc, silver, gold), the government facilitated foreign investment in the oil and mining industry. At the end of the 1950s, industrialisation took off. However, the industrial production was mainly to satisfy domestic demand, and the industry was little competitive and hardly generating foreign exchange. As a result, the industrialisation depended on the growth of the export of minerals, which was subject to the demand of developed countries. Though the mining industry only contributed 9% to the national income, it was pulling (or slowing down in bad economic times) the Peruvian economy, together with the fishing industry (especially the export of fishmeal), as these were the most dynamic, fast-growing sectors. The increased employment in the cities stimulated the migration from the rural towards the coastal urban areas. As the industrialisation grew slower than the urban population growth, the third sector of services with low-earning jobs (e.g. street vendors, domestic employment and construction) was growing the fastest (Gonzales de Olarte, 1994).

Economic politics have been unstable for the last decades, changing from orthodox to heterodox and back, which is also known as the '*péndulo peruano*'. This instability caused insecurity for investors, affecting negatively the investment rate and creation of employment and income (Gonzales de Olarte, 1997). During the orthodox (liberal) governments, investments were mainly made in infrastructure, whereas the heterodox (interference) governments invested in productive activities, mainly state companies (Gonzales de Olarte, 1994). The liberal government, who had power until 1962, considered foreign investment as a promising way towards modernisation, but did not bother about rural poverty or the unequal land distribution (Sheahan, 2001). Under heterodox governments state intervention and protectionism were heavily intensified. In 1985, a huge conflict arose between the government and the private sector when the government tried to nationalise the financial system. As the economy collapsed, violence increased (Sheahan, 2001). Rural areas in the Andes did not benefit from any economic and political changes. Investments were only made in sectors and areas with a sufficient economic (profit) and political (votes) return, ruling out the less profitable small-scale agriculture and the powerless rural areas (Gonzales de Olarte, 1994).

3.2.2 Impact of economic development on agriculture

The agricultural sector

The demand for agricultural products for urban consumption and agro-industrial use grew rapidly between 1950 and 1975 due to population growth, urbanisation and industrialisation, but the export demand and rural markets grew slowly or not at all. The production on commercial large-scale farms at the coast grew rapidly but this expansion was not sufficient to keep up with the growing food demand in urban centres. Whereas Peru used to be a net exporter of agricultural products, in the 1980s it turned into a net importer (Sheahan, 2001). The share of agriculture in the Gross National Product of Peru declined from 24% in 1950 to 15% in 1970 (Gonzales de Olarte, 1994), to only 8% in 2003 (WorldBank, 2004b).

The agricultural sector was exposed to a major liberalisation programme in the 1990s (the so-called *Fujishock*), inspired by the successful shock treatment in Chile (Mayer, 2004). This reform eliminated much of the highly interventionist policies, liberalised trade, eliminated price controls over agricultural products and most agricultural input subsidies (Escobal, 2001). The inflation was controlled, and the economy recovered, resulting in an agricultural production increase, even in the rural areas in the Andes. At the same time the Fujimori government made a major effort to invest in rural roads, electrification, and drinkable water and sewage systems in the rural areas (Escobal, 2001). This investment in rural areas and the successful elimination of the guerrilla restrained the increased inequality caused by the liberalisation (Mayer, 2004). Though the production increase helped to reduce poverty in the rural areas, opportunities outside agriculture are needed to alleviate poverty effectively in these areas (Sheahan, 2001).

Agricultural development in the Andes

According to Sheahan (2001), three factors restrained agriculture in the Andes: the distribution of land, lack of education and violence (guerrilla). The missing land market prevented the intensification and technological change in rural areas (Gonzales de Olarte, 1994). Former landowners removed their capital from the rural areas after the Agrarian Reform, as they had to give up their land (Sheahan, 2001). At the same time, imported food was subsidised to keep prices low for the urban population. Small-scale farmers were discouraged to intensify and produce for the market, as they lacked capital, technology and access to the markets. While the large-scale modernised farms at the coast increased their production to meet the increasing demand in the coastal urban areas, the small-scale farmers dropped out, as they could not compete. Due to their low productivity, high transportation costs and high risks it was not profitable for them to sell their products on the urban markets (Glave, 1992). They had the choice either to become subsistence farmers or migrate to the urban areas (Figueroa, 1989; Gonzales de Olarte, 1994).

The exclusion of small-scale farmers from the markets

The low productivity of agriculture in the Andes is mainly due to lack of dynamic markets (Kervyn, 1988). In order to understand the exclusion of the small-scale farmers from the markets, one has to consider the supply and demand of agricultural goods in Peru (Figure 3.2).

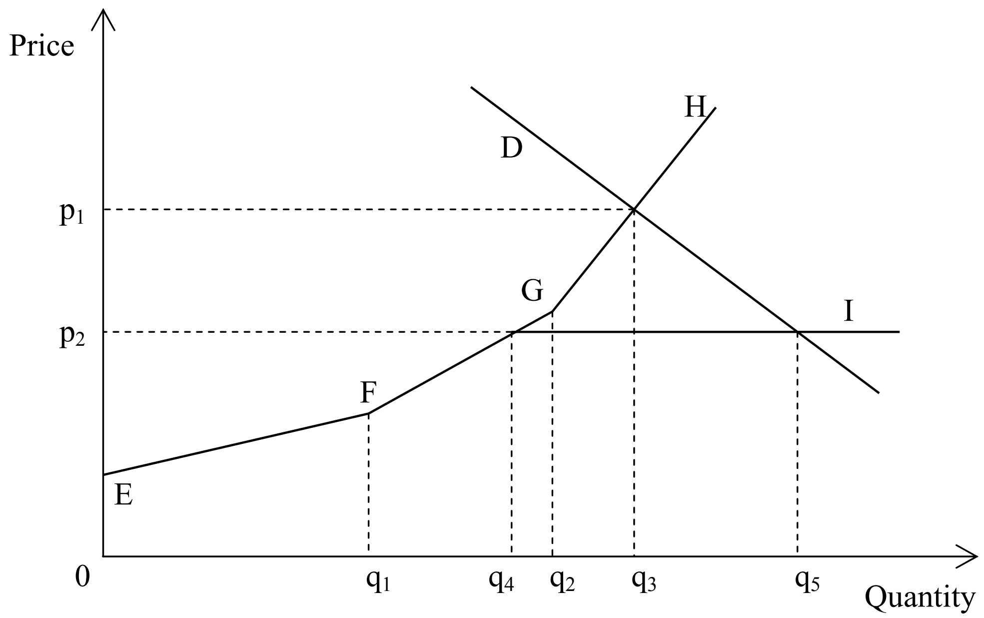

Figure 3.2 Supply and demand for agricultural products *(after: Gonzales de Olarte, 1994)*

The domestic supply of agricultural products in Peru (*EFGH*) is composed of the supply of commercial large-scale farms at the coast (*EF*), the supply of cooperatives (*FG*) and the supply of individual farm households (*GH*). When there is a demand *D*, the large-scale farms will supply $0q_1$, the cooperatives supply q_1q_2, and the individual farm households will supply the small amount of q_2q_3. All will receive the price p_1 for their products, which means that the large-scale farms and the cooperatives have a considerable profit. However, supply changes when agricultural products are imported from neighbouring countries for lower prices. The imported supply is presented by the line *I* and is supposed to be infinite elastic (Gonzales de Olarte, 1994). Now, the supply is presented by the line *EFI*: the large-scale farms supply $0q_1$, the cooperatives q_1q_4, and the rest, q_4q_5, is imported. As prices drop to p_2, it is not profitable anymore for the individual farm households to produce for the domestic market.

3.2.3 Peasant economy: the economy of small-scale farm households

The general sense of the debate in the 1970s and 1980s about peasant economy in developing countries (LDCs) was that it was tied to the wider political economy, resulting in an extraction of the surplus value from rural areas and constraining farm households' access to resources (primarily land), creating unfavourable relationships between rural people and the market and state. It was assumed that peasantry not only provided cheap food to the urban economy, but also cheap labour (Bebbington, 1999). However, according to Gonzales de Olarte (1986) this notion of functional dualism does not apply (anymore) for the peasant economy in Peru. Most of the agricultural products of small-scale farmers in the Andes are traded on rural markets, not on urban markets where imported and agro-industrial goods are traded. The peasantry does not supply cheap labour to urban areas either. The urban areas have sufficient labour available, as unemployment is high, and this labour is better qualified (skilled, higher education) than the peasant labour (Kervyn, 1988).

In the 1990s the discussion shifted towards the question whether peasant economies are viable or not (Bebbington, 1999). The peasant economy in the Andes is reflected as an impossible situation in which the peasantry limps along with low-productivity agriculture and migration, as the other options – disappear or modernise violently towards competitive production – are not very likely to happen (Niekerk, 1994). However, though *agrarian* livelihoods in the Andes might be in crisis, there are other *rural* livelihood options that offer sustainable alternatives (Bebbington, 1999). The farm households manage to adapt to extreme conditions like insufficient resources, unfavourable markets and a State that is insensitive to them (Mayer, 2004). Viable rural livelihoods are characterised by (Bebbington, 1999):

- A relative success of households to sustain or increase their access to different resources,
- Access to different opportunities to turn those resources into sources of livelihood improvement,
- Access to means through which these resources contribute to their livelihoods,
- Access to social networks and institutions in order to secure the other three types of access.

This view stresses the importance of social capital in a peasant economy. Social capital includes institutions, relationships, attitudes and values that govern interactions among people and contribute to economic and social development. Though social capital enables people to interact and gain access to resources and networks, it can also have a negative impact, as specific (ethnic) groups might be excluded from society or networks (Grootaert and Bastelaer, 2001). In the Peruvian Andes, social capital is partly institutionalised through peasant communities.

Peasant communities

Peasant communities are an important institution, as it determines the access of farm households to land and (extra-household) labour. The peasant communities are territorial groups whose members depend on each other via the exploitation of common resources and maximisation of the collective well-being (Kervyn, 1988). At community level there are two sorts of communal resources: natural resources like land and pastures, and created resources like irrigation structures, schools, and health centres (Gonzales de Olarte, 1994). Due to the social structure, efficient use is made of the marginal resources and technology, as farm households organized in a community have better possibilities to reproduce and develop than individual farm households (Gonzales de Olarte, 1986). The community structure helps to surmount the difficulties that individual households encounter due to economies of scale, like the proportion of production factors (especially labour), infrastructure, the scheduling of tasks, the extension of available land and the collective defence of the territory (Mayer, 2004).

De Vries and Gilvonio (2001) describe a peasant community as "a form of social organisation characterised by corporate control of land and other communal resources, the existence of rules and obligations enforced by communal decision-making bodies and, related to this, forms of reciprocal and communal labour (*faenas*) for the construction and maintenance of roads, irrigation canals, buildings, et cetera". The community is governed by the community assembly (*asamblea comunal*), which is formed by all adult community members. It is the highest organ that can take decisions and it elects the Communal Directive Board (*junta directiva comunal*). The latter legislates about access to natural resources and administers justice. The authorities of the communities enjoy a relative autonomy for their internal administration (Kervyn, 1988). They are recognized and legitimized by the Peruvian government (Gonzales de Olarte, 1986).

Farm households and rural livelihoods

A farm household is defined as a peasant family that (Ellis, 1988):

- owns a certain quantity of land, as well as means for production,
- uses mainly family labour for agricultural production (except during certain peak periods),
- is part of a larger economic system, and
- is partially engaged in markets, which tend to function with a high degree of imperfection.

A farm household in the Peruvian Andes is normally a nuclear family (Figueroa, 1989). The objective of the farm household is to assure its maintenance and reproduction. Production is meant for subsistence and interchange, in order to diversify consumption and increase levels of well-being. Farm households try to minimise variation in production, income and expenditure (Gonzales de Olarte, 1994). When farmers face a relatively known probability of risk (e.g. climatic risk) they establish insurance mechanisms, like crop diversification, dispersion of land or reciprocal labour exchange, in order to control the risk even if these mechanisms limit the production efficiency (Figueroa, 1989). More risks are taken, once the minimum income is assured, or when the opportunity cost of a production factor is low. For example, households take risks in labour allocation when household members migrate temporally to search for off-farm employment (Kervyn, 1988).

The principal resources for farm households are: arable land, pastures, livestock, water and irrigation structures. Labour is the largest resource, and the most flexible as well. Farm households' agricultural production is limited by three restrictions (Gonzales de Olarte, 1994):
- the agro-ecological zone defines the type of crop and type of livestock;
- the need for subsistence defines which products the household consumes and how much;
- the rural and urban demand defines the products farmers produce for the market (wheat, potato) even though they are not competitive, leaving those products for which they are competitive (olluco or quinoa), as there is no demand.

Agricultural production has not been sufficient to sustain the reproduction of the farm household for decennia, and farmers are therefore forced to look for other income opportunities outside the community (Araujo, 1986; Gonzales de Olarte, 1986; Figueroa, 1989). Escobal (2001) estimated that 51% of the net income of Peruvian rural households originates from activities other than farming. In order to assure a relatively stable income throughout the year, farm households undertake a portfolio of activities which are interwoven. Agriculture and livestock keeping are important to assure the household consumption. The remaining labour is dedicated to the production of Z-goods and to the labour market (Figueroa, 1989). The agricultural calendar determines the rhythm of labour allocation to the different activities (Figueroa, 1989). The interdependency of these activities may limit technical change, as a positive change for one activity may cause negative changes for other activities (Kervyn, 1988). Richer households tend to rely more on non-farm sources and on the commerce of agricultural products than the poor (Escobal, 2001; Mayer, 2004). The richer households are more capable of selling products, as they have more personal contacts, speak Spanish and have more capital. These households also have access to skilled off-farm employment, whereas poor households are mainly working as (unskilled) labourer at the local labour market. As members of rich households have a better education it is easier for them to adapt in unknown cities. Furthermore, they have 'working capital' which allows them to finance the travel of a household member, his accommodation and the time to look for a job (Figueroa, 1989).

Markets for labour, land and goods

Farm households in the Andes are partly integrated in the markets. On average, 50% of the total income (products obtained form agriculture, livestock, non-farm activities and selling labour off-farm) is destined for subsistence, and the other 50% is interchanged at the market, with livestock sales and labour bringing in most money. Goods that were produced in the community in the past (ceramics, food and drinks, clothing) are now replaced by goods produced in urban areas, like drinks, clothes and footwear (Figueroa, 1989).

The principal market failures in the rural Andes are (Agüero and Robles, 1997):
- *Externalities*: the social benefit is different from the private benefit due to the absence of infrastructure for transport or lack of technological innovations. Furthermore, environmental effects of fertilisers or pesticides use, or irrigation costs, are not considered in the prices for agricultural products.
- *Inadequate assignment of the user and owner rights* of common and public resources.

- *Absence or scarce development of markets* like markets for water and land. This includes an inadequate register of property rights, which hampers the growth of the land market. Also important are the imperfect information flows, as is the case for credit and labour markets.
- *Lack of competition*: this comprises the monopolistic structures in input markets.

The local labour market is partly non-monetary: i.e. the reciprocal labour exchange system. Normally, *ayni* is applied between poor farm households, whereas *minka* is between rich and poor households (the rich paying the poor). The amount of compensation depends on the personal relationships (Figueroa, 1989). The land market is very limited, as land is common property in most peasant communities. In 1995 a new law was accepted: '*nueva ley de tierr*'. This new land law created the possibility for community members to dispose freely their land and to manage their land individually. Farmers are interested to formalise their rights on the arable land for which they already have permanent user rights. However, at the same time they want to preserve the communal system and collective management of the pastures. There are still many practical problems that impede the implementing the new law into practice (Monge and Urrutia, 1997).

An important restriction for farm households is that they depend on the agro-ecological zone for the agricultural products they produce (Agüero and Robles, 1997). Also, there exists a certain inelasticity of a farm household's agricultural products in relation to its price. This inelasticity is not a result of traditional behaviour of farm households, but rather of the fact that the household's portfolio of activities is affected when the product of one activity is changed. For example, if the price of potatoes increases, it is impossible for a farmer to cultivate only potato, as other activities are important for his survival as well (Figueroa, 1989).

3.3 Concluding remarks

The Andes region has a complex geography, creating both opportunities and constraints to its development, as it is affected by its inaccessibility, fragility of natural resources and economic structure, marginality of productive activities and its diversity of agro-ecological zones. Political economic and demographic forces have dictated agricultural development. The peasant economy in the Andes has been marginalised, as the contribution of the agricultural sector to the economic development of Peru gradually decreased. However, small-scale agriculture did not disappear. On the contrary, peasants are increasingly integrated into markets, as they become less self-sufficient. The marginalisation of small-scale agriculture is thus the product of a national economic development that neglected modernising agriculture in marginal areas, and that could not absorb peasant labour either (Kervyn, 1988). Agriculture, and particularly food crops, has lost profitability in the open market context (Appendini, 2001). As a consequence, farm households undertake a portfolio of activities and always look for new opportunities to assure their livelihoods. Though agricultural production is still important for the survival of many households, as it assures their food consumption needs, it is not the primary source of income anymore.

This raises the question what the consequences of this marginalisation of Andean agriculture are for SWC. Rural households can adapt to environmental degradation, either by mitigating its effects on their livelihoods by depending less on the natural resources, or by rehabilitating degraded resources. Considering the soil, this implies that farm households either choose to become less dependend on agriculture, or to invest in soil improvement. Whether they choose for the first or the second option depends on their endowments, institutions and technologies (Scherr, 2000). However, most programmes aiming at poverty reduction and natural resource conservation in the Andes have tried to address poverty by introducing agricultural technologies and conservation interventions. Yet farm households with whom they worked depended on non-farm income activities or migrant remittances (Bebbington, 1999). This might explain disappointing responses to SWC interventions in some cases. On the other hand, due to the low revenues from agriculture, farm households can be ‘investment-poor’ (Reardon and Vosti, 1995), as they lack the assets to maintain their resources like land. Though land has become a less important resource for their income, it is still an essential resource for the livelihood of most farm households, ‘justifying’ SWC interventions.

Chapter 4

The research context

4 The research context

This research is executed in two areas in the southern part of the Peruvian Andes: the district Pacucha (department Apurímac) and the district Piuray-Ccorimarca (department Cusco). In both areas, programmes were undertaken to improve rural livelihoods and to promote sustainable agriculture and, more specifically, soil and water conservation (SWC). Most research was carried out in Pacucha. As many secondary data and information was already available on Piuray-Ccorimarca, less research was done in this area. This chapter describes the two research areas, the farm households, and the programmes and their activities. It is realised that the two research areas constitute two different case studies, each with a distinct bio-physical and socio-economic context, and with different SWC interventions.

4.1 Data collection in research areas

The information presented in this chapter is based on grey literature (e.g. programme reports), consultancy reports and fieldwork, which consisted of transects, household surveys and informal talks with programme staff and farmers.

Transect walks

In November and December 2001, transects were made in the two research areas. Based on field observations, different areas within each watershed were selected, in order to cover the heterogeneity of the area as much as possible. Accessibility on foot appeared to be an important restriction though. Once a slope was selected, a transect walk was made along a straight line. Characteristics on land use, slope, soil, vegetation, erosion and SWC practices in the immediate surroundings (up to 5 meter each site of the line) were noted. GPS, compass, an inclinometer, and a measuring tape were used as tools to determine and register the transect line.

Household survey

In January and February 2002 a survey was carried out among 180 farm households in Pacucha and 192 farm households in Piuray-Ccorimarca. A stratified sampling procedure was applied in order to ensure that sub-samples of programme participants would be sufficiently large to carry out statistical analyses. Within each strata farm households were selected randomly. Three strata were defined in Pacucha: farm households not participating in any agriculture-oriented programme; farm households participating in MARENASS; and farm households participating in PRONAMACHCS. In Piuray-Ccorimarca the following three strata were defined: farm households not participating in any agriculture-oriented programme; farm households participating in ARARIWA; and farm households participating in PRONAMACHCS. During the data collection in the latter area, it appeared that the first stratum was difficult to find. Almost all farm households encountered were PRONAMACHCS participants, of whom a large part was participating in ARARIWA as well. It might be that farm households who do not participate in any agriculture-oriented programme are not much interested in agriculture either, as they work off-farm, and were therefore not found at home by the interviewers.

After testing the survey form, local students with knowledge of agriculture and of the local language Quechua were recruited in order to carry out the survey. The survey forms were checked on a daily basis during the data collection period, in order to correct any mistakes made by the interviewer.

Cross-sectional data were collected on farm household characteristics, the farming system, characteristics of farmland, agricultural production, programme involvement, use of SWC practices, and the perception and opinion of the farm households. A few observations were left out of the analysis because of extreme values and unreliable or incomplete data.

Informal interviews

During different fieldwork activities (e.g. transects, yield measurements, survey, courtesy visits) informal talks with farmers were made as much as possible. Statements and opinions of farmers were noted in a fieldwork diary. Also programmes were visited regularly, in order to collect programme reports, but also to have informal discussions with programme staff. The discussions and exchanges of ideas with Peruvian researchers were another important source of information.

4.2 Description of research areas

Figure 4.1 shows the location of both research areas, Pacucha and Piuray-Ccorimarca. Both departments, Apurímac and Cusco, are characterised as poor. Apurímac is one of the departments with the largest percentage (78%) of poor[2] inhabitants. 75% of the inhabitants of Cusco are also considered as poor. The high percentages are related to the rural poverty, which is due to the low land productivity, reduced size of agricultural properties, bad infrastructure, difficult access to markets and lack of access to education and health services (INEI, 2002).

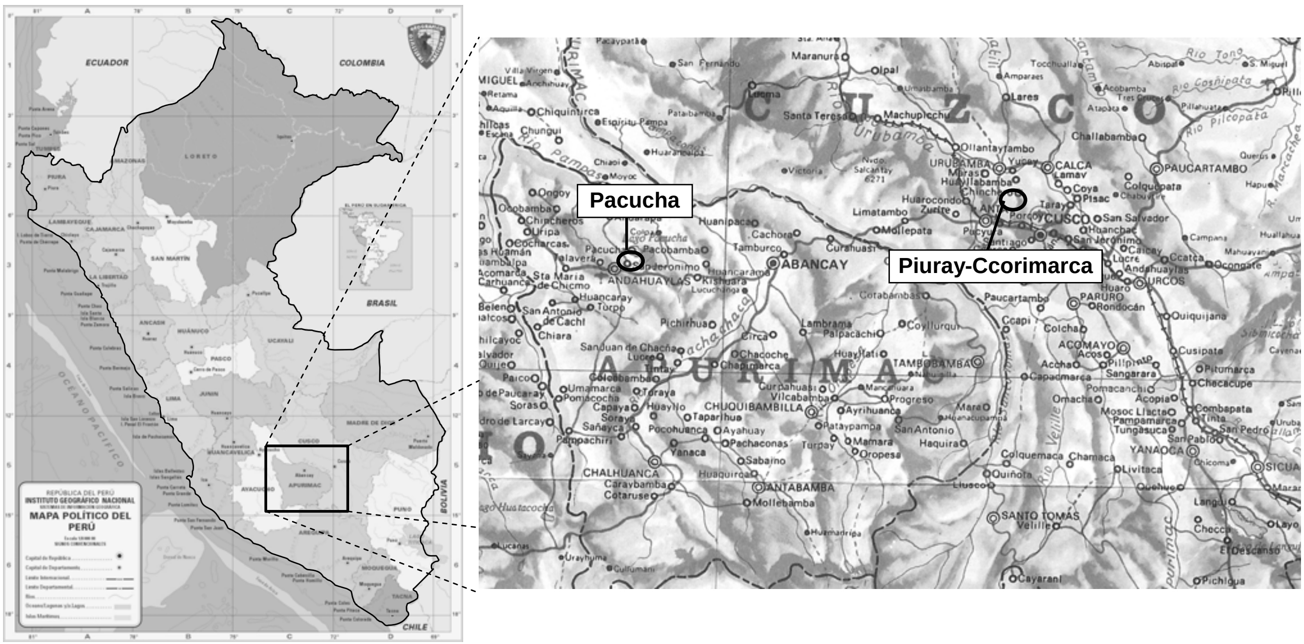

Figure 4.1 Location of research areas in the southern Peruvian Andes

[2] 'Poor' is defined, as not having the means to provide basic consumption of the household.

4.2.1 *Description of Pacucha*

Pacucha is situated in the province Andahuaylas. Population density in this area is about 48 persons km^{-2} (Philip and Reichard, 2002). Pacucha is situated at about 30 km from the small town Andahuaylas, connected by an unpaved road. Every Sunday there is an agricultural fair in Andahuaylas where farmers can sell or buy goods. Most farm households dedicate some time to off-farm activities like, trade, wage labour or fishing, to get some extra income. The lake attracts local tourists, but in very modest amounts. The local population does not (yet) profit from this tourism (mainly day trippers from Andahuaylas). In the 1980s, the guerrilla Shining Path was active in this area. During this period this region was difficult to access and therefore is less developed than other parts of Peru. People still suffer traumas of this frightening period. After the imprisoning of the guerilla leaders in 1992, programmes (re)started their activities gradually.

The district Pacucha is larger than the sub-watershed[3] considered in this thesis. The sub-watershed Pacucha (68 km^2) ranges from 3000 till 4000 m.a.s.l. The climate is thus temperate and the area can be defined as a *quechua* zone (see section 3.1.1). The geology in the northern part of the watershed is different from the southern part. The northern part is characterised by deep soils susceptible to mass movements like creep. Also karst[4] processes influence the landscape. In the southern part hardly any mass movements occur. Soils are shallow, and the geomorphology consists of gullies, denudational slopes and alluvial fans. East of the lake Pacucha, a large floodplain is formed. Also the vegetation is different in the northern and southern part. As the northern slopes are less exposed to sunshine than the southern part, the soils are more humid and vegetation is more abundant (Philip and Reichard, 2002).

Based on climatic data of the local weather station in Andahuaylas, it was calculated that the average annual rainfall over the period 1990 – 2001 was 697 mm (ranging from 441 mm in 1992 to 948 mm in 2001), with average annual maximum temperature of 20.5°C and an average annual minimum temperature of 5.6°C. Temperatures do not change much throughout the year, but rainfall does. The rainy season is from October till April, with January till March being the wettest months. During the dry season (May till September), minimum temperatures drop to 1 till 5°C. However, the weather station in Andahuaylas is situated at a lower altitude (about 2900 m.a.s.l.) than the sub-watershed Pacucha, so actual temperatures in Pacucha might be a few degrees lower. During the dry season night frost occurs at the lower parts of the watershed.

In November 2001 four transects (T1–T4) were made in the watershed[5], to explore the bio-physical features of the area (Figure 4.2). The four transects are presented in Appendix 4.1. Soils are silt

[3] When 'Pacucha' is mentioned in this thesis, it is meant the sub-watershed, not the district.

[4] Karst is a German word meaning 'bare stony ground', describing limestone terrain characterized by a lack of surface drainage, a discontinuous or thin soil cover, abundant enclosed depressions and a well-developed system of underground drainage including caves due to the solubility of limestone (Philip and Reichard, 2002).

[5] The transects were chosen in such a way that different landscape units were explored. Some parts of the sub-watershed were too steep (north-west) or were reforestation areas (south-west), and therefore not taken into consideration.

loam or loam, and slopes are steep. Different erosion features are present in the watershed. In the southern part, there is a risk of sheet erosion and gully erosion. The gullies in the reforestation area are vegetated and thus not active anymore. However, a few active gullies can be noticed in the arable fields. In the northern part creep and toppling of the soil take place. Farmers have adjusted their land use to the soil. The unstable soils in the north are used as pasture and are under permanent cover, whereas the shallow soils susceptible to sheet and gully erosion are reforested with eucalyptus. Different SWC practices are found in the sub-watershed: infiltration ditches in the upper parts with pasture, gully control, reforestation, and terraces in arable fields. However, terraces are small, and SWC practices are few and scattered along the slope. The SWC practices in the upper parts of the watershed are often neglected. These are the so-called *aynoka* fields (section 3.1.3), and thus are under communal management. Most of these fields are under fallow for several years and used as pastures. During this period, the SWC practices are not maintained. There are no ancient terraces in this area, so farmers do not have a history in terracing. According to Cavassa and Bedoya (2001) only 7% of the total area contained SWC practices, which are promoted by programmes.

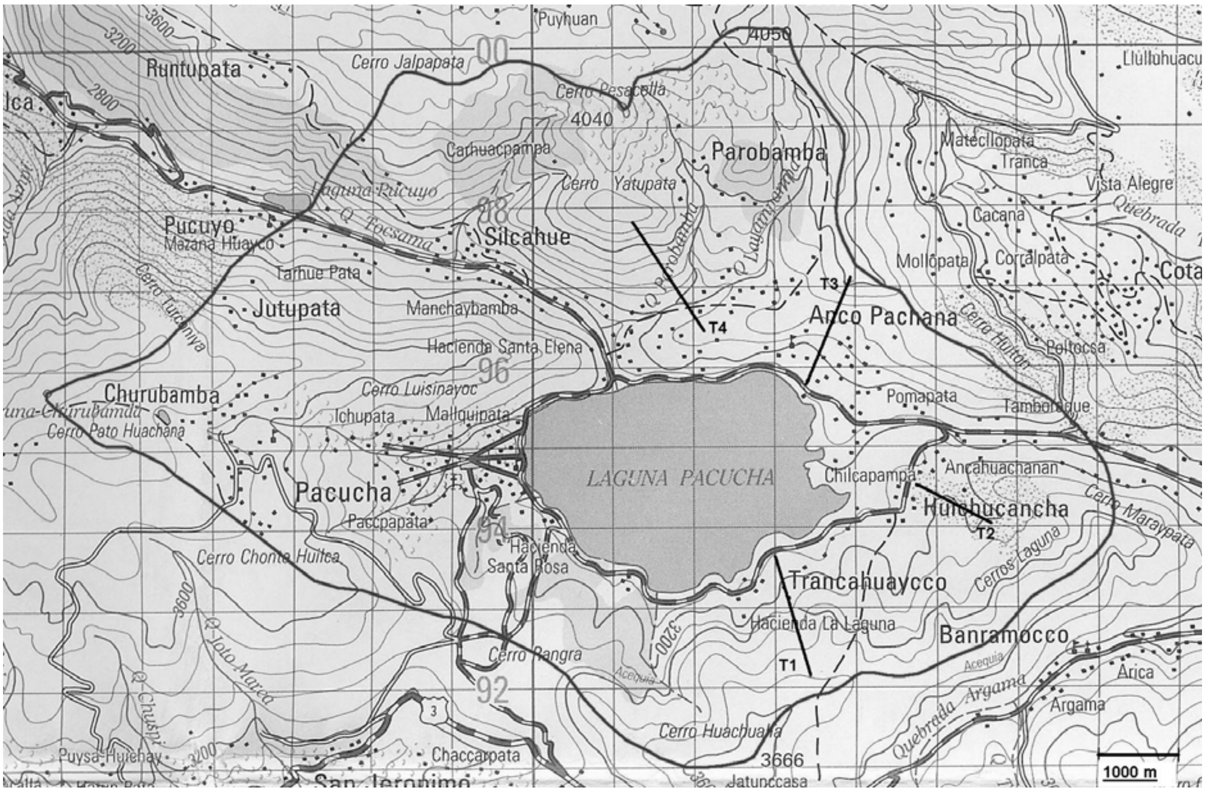

Figure 4.2 Map of sub-watershed Pacucha

Maize and potato are the main crops in Pacucha, and, to a lesser extent, barley, wheat and beans. Maize is cultivated at the lower fields of the slopes and in the floodplain, often in combination with irrigation. Cereals are cultivated at the higher and rainfed areas. Potato is cultivated anywhere in the sub-watershed, depending on the variety. Most farm households produce for their own consumption. Surpluses are sold on the markets in Pacucha or Andahuaylas. Potato is the main cash crop. Few chemical agricultural inputs are used. Livestock mainly consists of cows, sheep, pigs, poultry and guinea pigs. Dairy products (surplus) are sold locally. Two governmental programmes are promoting SWC practices in this watershed: MARENASS, during the period 1998-2003, and PRONAMACHCS since 1995.

4.2.2 Description of Piuray-Ccorimarca

The sub-watershed Piuray-Ccorimarca is situated in the province of Urubamba, department Cusco. A small part of the sub-watershed belongs to the province Anta. Population density in the area is 88 persons km^{-2} (Antezana, 2002). The sub-watershed Piuray-Ccorimarca is situated at 30 km from the departmental capital Cusco and reached by a well maintained paved road. The economic activities and tourism in Cusco and its surrounding villages have a large influence on life in this area. Most farm households work in agriculture, but they also spend considerable time on off-farm employment like taxi driver, porter on the Inca Trail or handicraft. Farmers are orientated towards the market, even though a large part of the harvest is still for home consumption.

The sub-watershed Piuray-Ccorimarca (96 km^2) ranges from 3300 till 4575 m.a.s.l. (Antezana, 2002). The agro-ecological zones encountered in the watershed are *quechua* (south-west) and *suni* (north-east). The watershed can be divided in two parts: Piuray (north-east), the area surrounding the lake Piuray that is characterised by steep slopes, and Ccorimarca (south-west), a flat area with gentle slopes and many problems of waterlogging, as drainage is lacking. Most erosion features and SWC practices can be found in Piuray (Guzman, 2002).

The rainy season is from November till March. Average annual rainfall is estimated at 824 mm (IMA, 2001). Average maximum temperatures are 20°C and average minimum temperature is around 0°C. In the upper part of the sub-watershed the annual average temperature is 7.5°C in contrast to the annual average temperature of 10.3°C in the lower part (IMA, 2001). From May to August night frost occurs in the upper part of the watershed, affecting the crops (Guzman, 2002).

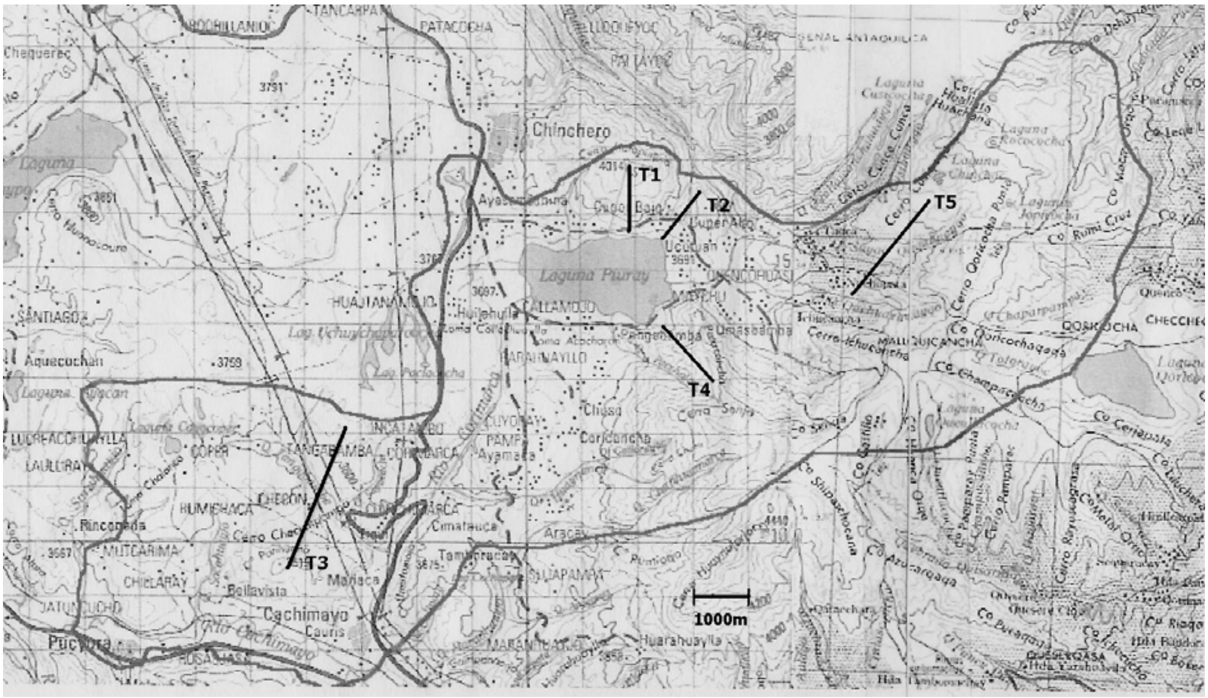

Figure 4.3 Map of sub-watershed Piuray-Ccorimarca

Five transects (T1–T5) were made in the watershed to explore the bio-physical features of the area (Figure 4.3). The five transects are presented in Appendix 4.2. The soils are mainly loamy sand or silt loam. Slopes of arable land are less steep than in Pacucha, and the valley bottom in the south-western part has very gentle slopes. Most erosion features are encountered in the north-eastern part of the watershed. Sheet erosion is often severe, but also signs of crusting, gully erosion and land slides are present. There is a diversity of SWC practices: infiltration ditches, slow-forming terraces, bench terraces, rehabilitated ancient terraces, naturally formed terraces (*pata pata*), et cetera. *Pata patas* are small natural terraces that have been formed by the accumulation of soil due to gravity and tillage. The bank is normally covered by native shrubs (Callañaupa and Egas, 2000). In some parts of the watershed the SWC practices are badly maintained if not abandoned completely. This happens often on communal land, the so-called *aynoka*. About 63% of the total area in the north-eastern part of the watershed (Piuray) contains SWC practices promoted by programmes (Cavassa and Bedoya, 2001).

Main crops are potato and other tubers (oca, olluco), and, to a lesser extent, beans, oat, barley and wheat. The latter three are mainly used for fodder. In the lowest part of the watershed some maize is grown. The crop potato suffers from many pests and diseases. All farmers use chemical inputs (fertilizers and pesticides) for potato. Contamination of drinking water due to these chemicals has become a problem. Livestock consists of cows, sheep, poultry and guinea pigs, and in the higher parts also some llamas and alpacas.

4.3 Farm households in the research areas

The value of the agricultural production is not significantly different between the two areas, but the income level from off-farm employment is significantly higher in Piuray-Ccorimarca (Table 4.1), as there are more off-farm opportunities. Also, the education level of the head of household is higher in Piuray-Ccorimarca. Though the agricultural production is not significantly different, more agricultural production (mainly potato) is destined for the market in Piuray-Ccorimarca. These differences suggest that farm households in Piuray-Ccorimarca are more integrated into the markets than farm households in Pacucha.

Farmland seems to be less suitable for agricultural production in Pacucha: less land is located in the valley bottom, slopes are steeper and more land has stony soils. Farmers were asked about their opinion and perception of soil erosion and SWC practices (Table 4.2). Soil erosion and decreasing soil fertility are considered major problems at farm level in both areas. Knowledge about soil erosion and SWC seems to be more widespread in Piuray-Ccorimarca than in Pacucha, probably due to the long period of SWC interventions. Many farmers observe negative effects of soil erosion. Soil loss, production loss, crop damage and loss of inputs, are most often mentioned as problems due to soil erosion. Most farmers seem to be well aware of the causes and effects of soil erosion, especially in Piuray-Ccorimarca. However, the reasons to implement SWC practices on their farm was not to prevent these negative effects, but rather because it was recommended by the programmes. Most farmers also mentioned the same SWC practices that are promoted by the programmes as solutions for soil erosion. In Piuray-Ccorimarca, some farmers also stated they had installed the practices because of the incentives they could obtain (i.e. money, food or tools).

Table 4.1 *Description of farm household characteristics*

Independent variables		**Pacucha (N=176)**		**Piuray-Ccorimarca (N=188)**		
Variable	**Description**	**Mean**	***St.dev.***	**Mean**	***St.dev.***	
Farm household characteristics						
Family size	Total amount of farm household members	5.108	*1.987*	4.745	*1.889*	*
Gender	= 1 if gender of head of household is male, 0 if female	0.835	*0.372*	0.957	*0.202*	***
Age	Age of head of household	39.8	*13.0*	40.0	*12.6*	
Education	Ranking of education level of head of household	2.659	*1.259*	3.239	*1.329*	***
Dependency ratio	Number of household members younger than 16, divided by total number of household members	0.459	*0.223*	0.454	*0.217*	
Farm household assets						
Off-farm income	Total amount of off-farm income (S/.) that farm household earned during year 2001	1943	*2084*	3969	*5426*	***
Agricultural production	Monetary value (S/.) of farm household's agricultural production of the year 2001	1234	*1512*	1578	*2753*	
Farm area	Total amount of hectares farmland owned by farm household	1.068	*1.409*	0.728	*1.166*	*
Livestock	Monetary value (S/.) of livestock owned by farm household	2523	*1901*	2417	*1585*	
Farm household behaviour						
Market	Ratio of total agricultural production that is sold on the market	0.136	*0.210*	0.315	*0.231*	***
Off-farm / farm income	Amount of off-farm income divided by total value of farm production: crop and livestock	0.952	*0.190*	1.439	*1.956*	***
Farmland characteristics						
Valley	Ratio of total farmland located in valley	0.361	*0.357*	0.573	*0.376*	***
Rainfed	Ratio of total farm without access to irrigation	0.422	*0.348*	0.395	*0.400*	
Gentle slope	Ratio of total farm with gentle slopes	0.446	*0.386*	0.355	*0.367*	**
Steep slope	Ratio of total farm with steep slopes	0.201	*0.333*	0.085	*0.205*	***
No stones	Ratio of total farm without stones	0.374	*0.361*	0.697	*0.352*	***

Means of both watershed are significant different at (*) 0.1 level, (**) 0.05 level, (***) 0.01 level

Reasons not to install SWC practices were lack of time, lack of knowledge or programme assistance (especially in Pacucha), or because it was not necessary (especially in Piuray-Ccorimarca). These results suggest that SWC practices are more common in Piuray-Ccorimarca and that these practices are implemented on most of the sloping and degraded land, whereas in Pacucha the diffusion of these practices is not as far. As the SWC interventions are more recent in Pacucha, this was expected. Also, more farmers copied the practices (without programme influence) in Piuray-Ccorimarca, indicating a more widespread diffusion of the SWC practices.

Table 4.2 *Opinion and perception of farmers concerning soil erosion and SWC*

Issue	Answers [1]	Pacucha (N=176)	Piuray-Ccorimarca (N=188)
Problems at farm level	Decreasing soil fertility	25.0%	26.1%
	Soil erosion	36.7%	30.3%
	Frost & hail	14.4%	17.6%
	Pests & diseases	5.0%	18.6%
Causes of erosion	Rainfall	77.2%	71.3%
	Runoff	16.7%	5.9%
	Steep slopes	35.6%	42.6%
	Inappropriate practices	10.6%	21.3%
	Excessive irrigation	5.6%	8.5%
	Does not know	8.9%	4.3%
Effects of soil erosion	Soil loss	50.0%	69.7%
	Loss of production	49.4%	29.8%
	Crop damage	54.4%	26.1%
	Loss of seeds	20.6%	12.2%
	Loss of fertilisers	21.1%	9.6%
	Sedimentation	9.4%	20.2%
	Does not know	13.3%	4.3%
Solutions for erosion	Slow-forming terraces	53.9%	70.7%
	Bench terraces	53.9%	65.4%
	Infiltration ditches	58.9%	60.6%
	Ancient terraces	-	27.7%
	Reforestation	28.9%	53.2%
	Contour ploughing	25.0%	26.1%
	Organic fertilisers	30.6%	9.6%
	Does not know	10.0%	3.7%
	Number of solutions mentioned	2.7	3.3
Reasons to install SWC practices	Recommended by programme	53.3%	39.4%
	To receive programme incentives	4.4%	15.4%
	Expected agricultural benefits	4.4%	14.4%
	Has others seen doing it	5.6%	10.6%
	Soil improvement	3.3%	5.3%
Reasons not to install SWC practices	Not needed (flat land)	20.6%	70.7%
	Waiting for programme assistance	21.1%	6.9%
	Lack of time / labour	30.6%	10.6%
	Lack of knowledge	8.9%	3.2%
Reasons to abandon SWC practices	No practices abandoned	85.6%	80.3%
	No benefits obtained	1.1%	2.7%
	Programme ended	2.8%	1.6%
	Lack of labour	7.2%	9.0%
	Lack of means	0.6%	5.9%

[1] Only the most often stated answers are presented here

4.4 SWC interventions in the research areas

4.4.1 Programmes with SWC activities

There are many NGO's and governmental programmes in Peru, especially in the Andes. Also in the two research areas various programmes are present. The programmes most important for the promotion of SWC practices are MARENASS and PRONAMACHCS in Pacucha, and the NGO Arariwa and MIMA-PRONAMACHCS in Piuray-Ccorimarca. Descriptions of the different programmes are given below.

MARENASS

MARENASS (Manejo de Recursos Naturales en la Sierra Sur) is a pilot of the Ministry of Agriculture, and started in 1998. The main goal of MARENASS is to intensify the agriculture and increase the commercial value of productive natural resources. The programme promotes a range of activities like: improvement of pastures, SWC, house improvement, horticulture, sanitary facilities, construction of corals, preparation of compost, handicraft, public works in community, empowerment, and increasing community dynamics. All activities are aimed to increase agricultural production and improve rural livelihoods. The main distinctive features of the programme are the participatory demand-driven approach, the emphasis on empowerment and the organisation of farmer competitions (called PachaMama Raymi) on several activities. The competitions are organized at community level, with farm households competing against each other, and on district level, with communities competing. At each competitions three prizes can be won, which consist of a certain amount of money to be received in the form of a cheque. Participants select the jury members, who judge the work done by each participating household.

When a community agrees on joining with the programme, a contract is signed between the community and MARENASS. The community has to open a bank account, to which funds are transferred that are destined for different programme activities. Participation of community members is voluntarily. MARENASS uses community promoters (*promoter communal*) as intermediaries between the programme and community members. These promoters are leading farmers with management skills, and selected by the community assembly. In Pacucha there used to be only one community promoter for the five communities participating in the MARENASS programme. But after two years they added two more, as it appeared that the promoter spent most of his time in his own community.

MARENASS' methodology is based on three pillars: support, productivity and sustainability (Figure 4.4). MARENASS provides financial support to the communities (the first pillar). FAT (*fondo de asistencia técnica*: \$2500) is a fund that enables participating communities to hire technical assistance. The fund FPC (*fondo de producción y comercialización*: \$1500) is meant for women, to stimulate their commercial activities. FOPRO (*fondo para pago a promotores comunales*: \$85 per month) is spent on the salary of the community promoter. The fund FOPRE (*fondo de ausipicio de premios*) provides the money for the prizes of the competitions. After four years all financial support to the community ends.

Productivity consists of knowledge transfer in order to improve agricultural productivity. This knowledge transfer is achieved through farmer-to-farmer extension and is demand-driven. The community hires temporarily technical assistance, the *yachaq*, with the money of the FAT. A *yachaq*, which can be a farmer with much experience, a consultant or a technical staff member of any programme, trains several farmers, the *yachachikoq*, in certain topics. The *yachachikoq* are selected by the communities participating in the MARENASS programme. After the training, the *yachachikoq*, on their turn, teach other community members the new techniques they learned. The objective of this extension system is to create a local knowledge market.

Sustainability (the third pillar) refers to the attempt to raise consciousness among the farmers that a sustainable management of their natural resources can improve their livelihoods and welfare, as well as their children's. Empowerment is an important aspect of the programme. Communities have to manage themselves the funds they receive. They also have to organize the trainings, by inviting experts (professional or other farmers) on a certain theme they find important. All activities carried out in the community, are organized by the community council or the promoter. However, they can get advice from MARENASS on how to manage the administration, or where to find experts. The idea of this organisation structure is that the programme staff should be as few as possible, and participants should do most of the work.

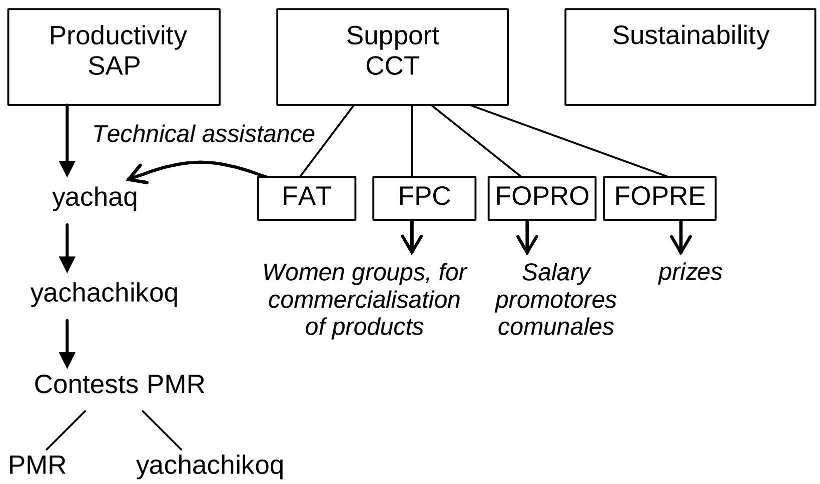

Figure 4.4 Three pillars of MARENASS

In Pacucha it seems that MARENASS achieved success at household level. Most of the participants are very pleased with the knowledge they gained, their self-development and empowerment, and the work they did. However, many commented that four years is not enough. They need a few years more of the programme's support, to be able to continue on their own. At community or watershed level, the programme cannot be considered a success in Pacucha. Some 'private' communities were not allowed to participate, as they are not officially registered as peasant community, and therefore MARENASS could not sign an agreement with them. In other communities, some households were not able or willing to participate, and the participation rate stayed low (10 to 20 % of the community members). This is due to bad relationships between community members. It seems that the intervention of MARENASS increased the bad understanding in some communities. Therefore, the impact of the activities on watershed level is quite low. The success of this type of programme depends largely on the influence of the community promoter, and on the internal organisation of the community. However, MARENASS has been more successful in other, more remote and poorer, areas. In total the programme worked in 360 communities, reaching about 33,000 households which is 60% of the total population of these participating communities (Zutter, 2004).

PRONAMACHCS

PRONAMACHCS (Programa Nacional de Manejo de Cuencas Hidrográficas y Conservación de Suelos) is a programme of the Ministry of Agriculture and was created in 1981 in order to promote SWC in the Andes. In the first two initial stages (1981-1986 and 1987-1992), PRONAMACHCS played a supplementary role within the public agricultural sector. The main objectives were: develop and experiment with techniques for conservation of natural resources in the Andes; transfer of proven techniques to the target group; strengthening of the conservationist consciousness in public and private organs. In the third stage (from 1993 onwards), the conservation objectives were incorporated in the objectives of the central government. The main objective of this third stage was the integrated treatment of resources (water, soil, plants) of selected sub-watersheds in the Andes. The following tasks can be distinguished: investment in marginal areas in order to increase the production capacity by investing in production means, services and infrastructure, including irrigation structures; participation of the population in the execution of programme activities by providing labour; promotion of SWC practices with use of direct incentives like food, tools and inputs (Heredia, 1997). According to PRONAMACHCS, lack of knowledge is the principal restriction for farmers to implement SWC practices. Technology transfer is the solution to promote SWC. By involving the farmers in the SWC activities, they learn how to implement these practices and at the same time they can observe the impacts (Chang-Navarro, 1986).

In 2000, PRONAMACHCS worked in 866 watersheds situated in 18 departments, which is equivalent to 133 provinces or 942 districts. It is estimated that in this year 232,772 households were reached. The programme is financed for a period of 5 years by the World Bank (US$ 51 million), and the Peruvian government (US$ 14.3 million), whereas the local population contributes its labour force with an estimated value of US$ 27.9 million. In 1995 the area with SWC practices was 12,067 ha, increasing to 38,920 ha in 2000. Half of this area constituted of slow-forming terraces, 39% was with infiltration ditches and the rest with new or rehabilitated bench terraces (PRONAMACHCS, 2000). PRONAMACHCS has agencies in the whole Andes region, and can reach almost every Andean farmer with its activities. It is said that the former president Fujimori used this programme first to control the guerilla, and later to ensure votes of the rural people during elections. In each village PRONAMACHCS organizes activities once a week under the direction of a technical engineer. Each household that supplied at least one member a week to participate in the activities receives tools at the end of the year.

In 1998, PRONAMACHCS started a new programme[6] with a sub-component called MIMA (Manejo Intensivo de Microcuencas Altoandinas). This was a pilot programme carried out in 6 sub-watersheds in the Peruvian Andes. The objective of MIMA is to increase the income of rural families and alleviate poverty through adequate and sustainable management of the natural resources (Gonzales and Antezana, 2003). MIMA works intensively in the selected sub-watersheds to promote watershed management through knowledge transfer, making use of research tools like participatory approaches and GIS. MIMA was also implemented in the sub-watershed of Piuray-Ccorimarca (Antezana, 2002), which is considered a successful case.

[6] The new programme was called 'Proyecto Manejo de Recursos naturals para el Alivio de Pobreza en la Sierra': project of natural resource management for the alleviation of poverty in the Andes.

Arariwa

In 1984, the NGO Arariwa[7] was established and started development experiments rather than programmes. During the years, however, the NGO developed more activities and covered a larger intervention area, that is, 8 of the 13 provinces in the department Cusco. The objective of Arariwa is to contribute to economic growth and sustainable development through the expansion of capabilities and rights of the population, improving the quality of their lives, promoting their cultural identity, and consolidate the democratic institution (Arariwa, 2004). Arariwa's intervention is based on four components (Cavassa, 2004):

- Promotion: contributing to sustainable rural development, focussing on knowledge transfer (agriculture and livestock, institutions and family health) while working with the local population.
- An education centre on integrated rural development (CENFOPAR): training for young people from peasant communities on subjects like agriculture, leadership, personal values, et cetera.
- Microfinance: financial services, promoting savings, training on communal banks.
- Small businesses (SEMAR): promoting commercial activities like crop and animal production, transformation of agricultural products and commercialisation.

Arariwa also promoted SWC practices in the past, like infiltration ditches, slow-forming terraces and rehabilitation of ancient terraces. By installing infiltration ditches in the upper parts of the sub-watershed of Piuray-Ccorimarca, Arariwa wanted to reduce the waterlogging problems in the valley bottom in order to intensify the cultivation in the valley. In order to stimulate farmers to participate in the installation of these practices, Arariwa paid for the labour. In the beginning, farmers received full payment but over time a certain percentage of the payment was destined for funds to be spent on public goods like electrification, improvement of school building, or road construction (Gonzales and Antezana, 2003).

4.4.2 Reflections on SWC interventions in research areas

SWC interventions and practices

Appendix 4.3 gives an overview of the SWC practices that are promoted by the programmes. Most programmes promote especially mechanical practices, like slow-forming terraces (PRONAMACHCS), bench terraces (MARENASS) and infiltration ditches. MARENASS is the only programme that pays also attention to organic fertilisers. But little or no attention is paid to agronomic practices like crop rotation, cover crops, protection of field boundaries or mulching.

Successful intervention

The most successful community in Piuray-Ccorimarca in terms of widespread participation in programme activities and technology adoption is Taucca. Arariwa as well as PRONAMACHCS claim this success. According to programme staff, there are several reasons for the successful

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[7] Arariwa is a Quechua word meaning 'guardian of the crops and animals' or 'mayor of the fields'. This guard not only anticipates and defends the crops against damage by animals and thieves, but also provides knowledge on agriculture, keeps up with the agricultural calendar, and represents the community in front of nature and the gods. He therefore has a huge responsibility. The name Arariwa was given to the NGO by a group of farmers with whom the NGO had been working during 8 years.

interventions. The community is situated in the upper part of the watershed and none of the farmers are working in Cusco. Agriculture is thus their only source of income (Scheelbeek, 2004). Another important factor is that 80% of the households are member of the Evangelic Peruvian Church. This changed the people's behaviour: they do not drink alcohol which is a huge problem in many communities in the rural Andes; a saving and hard-working attitude is created; and virtues like punctuality, honesty and solidarity are important in daily life (Gonzales and Antezana, 2003). Nowadays, Taucca is the demonstration area for visiting farmers and organisations.

In Pacucha, the most successful community in SWC is Manchaybamba. This community is located in a steep narrow valley, and little land is available for agriculture. Livestock was pastured on the very steep slopes and pasture land was degraded. However, bench terraces enabled irrigation on the lower parts of the slopes, and farmers started to grow alfalfa. With this alfalfa they feed their (improved) livestock, and as a result milk production increased and women had to spend less time on livestock herding.

Conflicts between programmes

Often various programmes work in the same sub-watershed, focussing on the same target group. However, each programme has its own interests, and wants to realise visible results within a short period in order to assure continuity of funding. Direct incentives are often used as an instrument in the competition for participants and results (Cavassa and Bedoya, 2001). Programmes blame each other that the others 'buy' the farmers and that the adoption of SWC practices achieved by the other programmes is not sustainable, whereas their own approach is the right one. This competition posed a serious problem in Piuray-Ccorimarca, and to a lesser extent in Pacucha as well. In Piuray-Ccorimarca, conflicts existed between PRONAMACHCS and Arariwa for one decade. The first one provided food or tools and the latter paid the farmers for their labour. Sometimes it happened that both programmes considered the same SWC practices as their achievement and the same farmers as their promoters. In Pacucha same conflicts existed between PRONAMACHCS and MARENASS: one person was the promoter of both programmes as well, and there was no coordination between the different programmes (Cavassa and Bedoya, 2001).

In 2000 a process was started in order to coordinate the activities of the different programmes in Piuray-Ccorimarca and to decrease the competition. The two watershed management committees (one for Arariwa and one for PRONAMACHCS) were combined in one, in order to tune the activities and empower the local population (Antezana, 2002). Though the Watershed Management Committee should be an intermediate between the farmers living in the watershed and the organisations working in the same area, in practice the committee became the representative of the programmes instead of the farmers. The (N)GO's still determine the agenda of activities, and the competition for participants as well as for donors continues, as they threaten each other's right to exist (Scheelbeek, 2004).

Conflicts between participants

In some of the communities in Pacucha, the same households participating in the MARENASS activities, won every competition, and thus received all the prize money. This caused jealousy, and 'losers' thought this was unfair and they were discouraged to continue the activities. Rumours were started about biased jury members. Another complaint was that large farm households had more labour available, and therefore won the competitions, as they were able to spend more effort in the implementation. Therefore, it was decided to compete among groups of families, instead of individual families. The participants of each community divided themselves among three groups, who worked together according to the *ayni*-principal. As there were always three prizes to hand out, each group received a prize. In this way, each participating household got some money, according to the amount of labour delivered. This distribution of the prizes (the incentives) was considered fairer.

Another problem in some communities in Pacucha was that the families, who participated in MARENASS since the beginning, did not allow other families to participate. Some farm households wanted to participate in the programme after they saw the first results. As the funds provided by MARENASS are destined for the whole community, this should be possible. But some participants prevented others to enter the programme, because of existing rivalry between families.

Attitude of programme staff and participants

Some field staff of PRONAMACHCS addressed the issues of the importance of motivated programme staff for a successful intervention, and the limited possibility they had to adapt the programme's objectives and approaches to local circumstances. Heredia (1997) found that most staff of PRONAMACHCS are mainly concerned about finishing their (quantitative) tasks in order to ensure their job, rather than that they are concerned about natural resources or rural livelihoods. The target group of PRONAMACHCS has two main reasons to participate in the programme activities. Firstly, the benefit of the SWC practices to reduce the agricultural risks and to assure the reproduction. Secondly, to obtain the benefits of incentives. The participants consider the two objectives as complementary. They search for possibilities to secure the reproduction of the household and a better use of the natural resources at their disposal. There exists interdependency between the programme staff and the participants: they need each other to satisfy their personal objectives, but this bond does not have anything to do with ethical reasons like altruism, conservation, et cetera. Behaviour of all actors is determined by short-term benefits. Furthermore, as PRONAMACHCS has a central top-down structure, there is no room for adaptation of interventions to local circumstances. This top-down approach created structures of interaction that provoke all actors to aim at small short-term benefits, instead of strengthening the capacity of field staff and the target group (Heredia, 1997).

The role of programme incentives

Cavassa and Bedoya (2001) carried out a study on the effect of programme incentives in four watersheds, among which Pacucha and Piuray-Ccorimarca. In their research, farmers confirmed that if there had not been incentives for SWC practices, they would not have installed these practices. However, spontaneous adoption sometimes occurs when farmers obtain direct benefits. In some cases, extension agents and technical staff have the feeling that their 'message' is not worth it if they have no incentives to offer. Farmers have an ambivalent opinion regarding programme incentives. They acknowledged the positive as well as the negative effects. As positive effects they mentioned: involvement in SWC, financial revenues, and access to knowledge. As negative effects they considered: dependency, conflicts because of jealousy, and indifference for other voluntary community activities. There was no relationship between type of incentives and adoption rate of SWC practices. Instead, community leadership and availability of labour seemed to be more important factors. When SWC practices were implemented on communal land, direct programme incentives became more important to stimulate the installation. The programme incentives allowed a large participation of the population, as well as the construction and rehabilitation of SWC practices. But at the same time the programme incentives formed a disincentive for future maintenance.

The authors conclude that programme incentives, like competitions and farmer-to-farmer training, and market incentives are the most appropriate to achieve sustainable adoption of SWC. Programmes should be transparent and use a participative approach. Two main problems are identified that should be solved:

- Lack of labour and a weakened social organisation of Andean communities complicate collective action, hampering the sustainable management of natural resources.
- Bad access to the markets, and low prices for products, limit the possibilities of economic improvement that could be obtained through SWC. Infrastructure and information about the markets have to be improved to solve this problem.

Programme incentives and target groups

Appendix 4.4 gives an overview of the programme and market incentives that play a role for the promotion of SWC practices in the research areas. A programme incentive can be interesting for a specific target group, and not for another. The food-for-work incentive of PRONAMACHCS was attractive to, and meant for, poor farm households with low food security. The farmer competitions of MARENASS seem to attract innovative farmers who are eager to learn and have sufficient assets (labour or capital) to invest in new technologies. The cash payments of Arariwa might especially attract farm households with little land but abundant labour, who look for off-farm opportunities to increase their income. Programmes have to be well aware of which target group they want to reach, and which incentives attract that particular group.

4.5 Concluding remarks

The geographic and institutional contexts differ between the two research areas Pacucha and Piuray-Ccorimarca. Pacucha is located in the *quechua* zone, and maize, beans and potato are the main staple crops. Piuray-Ccorimarca is situated at a higher altitude, in the *quechua-suni* zone, with potato as the main crop. Access to markets is better in Piuray-Ccorimarca than in Pacucha. Therefore, farm households in Piuray-Ccorimarca are better integrated into the markets for off-farm labour and for agricultural products, than those in Pacucha. Note that the heads of the farm households in Piuray-Ccorimarca also have a higher education level.

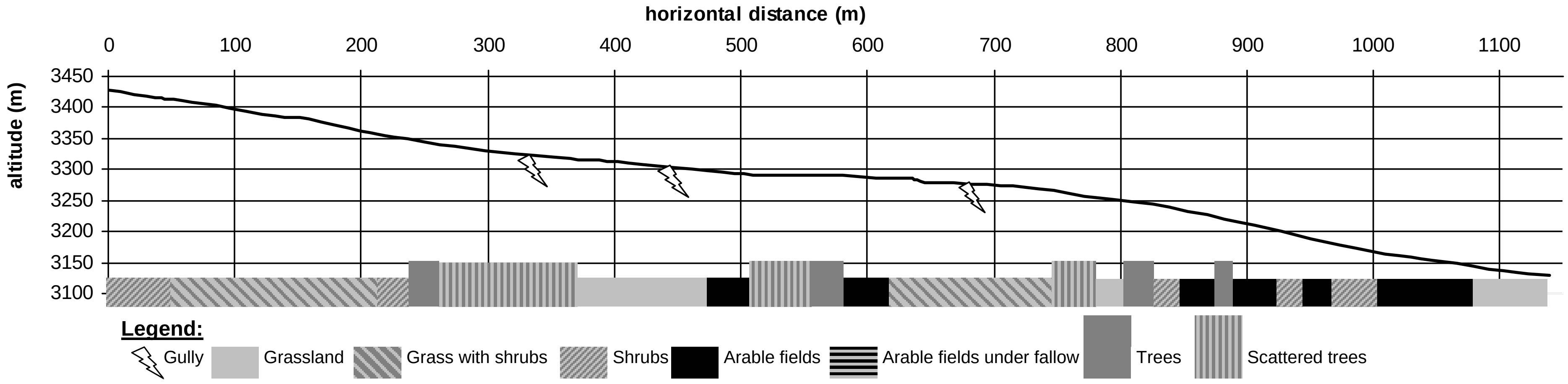
Due to different soils and climate, erosion features are different as well. Nevertheless, the same SWC practices are promoted in the two areas: bench terraces, slow-forming terraces, infiltration ditches and reforestation. SWC practices have been promoted in Piuray-Ccorimarca since the early 1980s. In Pacucha though, SWC interventions are more recent, as this area was inaccessible due to extreme violence till 1992. Farmers' explanations why SWC practices are less common in Pacucha than in Piuray-Ccorimarca were that they had not sufficient time, no knowledge or were still waiting for programme assistance. This latter statement illustrates the paternalistic dependency that has been created over the last decades because of state interferences and the presence of many

(N)GOs. An important reason for farm households to implement SWC practices was because programmes, in which they participated, recommended this. External intervention has been the key driver of SWC implementation for a long time. It partly depends on the local geographic (e.g. Manchaybamba) or socio-economic (e.g. Taucca) context whether these external interventions are successful or not. Each programme has its own philosophy and approach that fits a specific type of farm household. However, they all ‘fish in the same pond’, and this often causes conflicts between different programmes. The same can happen the other way around. Participants do not want other households to participate, as they fear that they will receive less benefit when they have to share.

APPENDIX 4.1

Transects in Pacucha

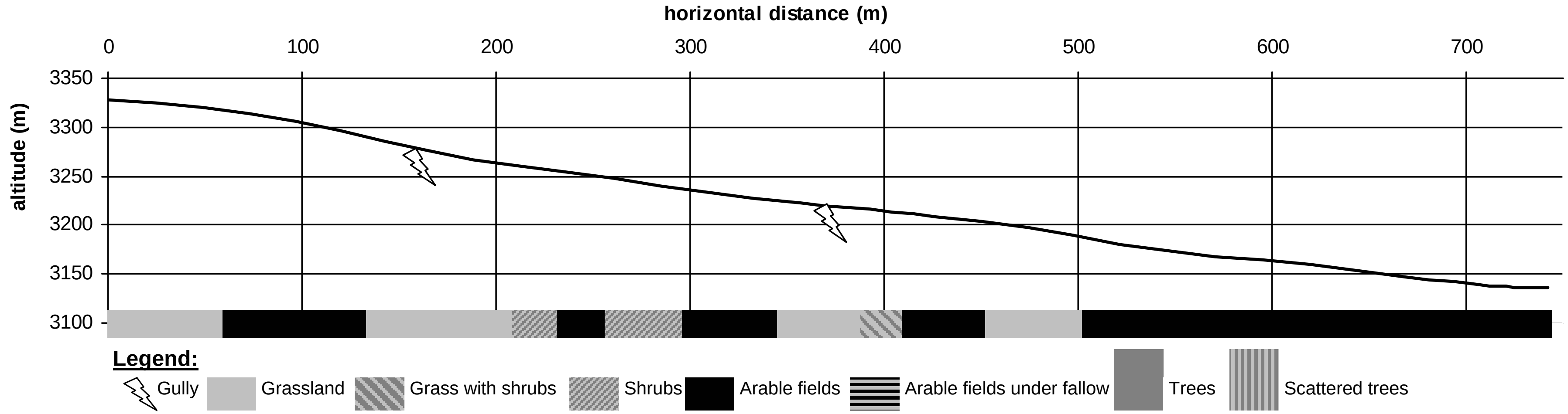
Transect 1 Community of José Olaya (starting point: S13°37.970’, W073°18.694’; ending point: S13°37.361’, W073°18.910’)



Vegetation	Grasses, shrubs	Grasses, herbs, cactuses	Grasses, cactuses, eucalyptus	Grasses, eucalyptus	Grasses, herbs, stones	Grasses, eucalyptus	Grasses, herbs, cactus	Grasses, cactus, eucalyptus	Grasses, shrubs, eucalyptus	Grasses, shrubs	Grasses, shrubs, cactus
Soil cover	50 – 95%	40 – 50 %	40 – 65 %	20 – 90 %	70%	60 – 75%	15 – 55 %	20 – 90 %	50 – 95 %	50 – 75 %	60 – 95 %
Max. slope	65 %	70 %	75 %	75 %	60 %	50 %	45 %	55 %	55 %	60 %	50 %
Slope transect	10 – 35 %	30 – 45 %	30 – 45 %	10 – 30 %	15 – 20 %	2 – 8 %	2 – 10 %	20 – 30 %	45 – 50 %	40 – 45 %	20 – 40 %
Soil texture	Silt loam	Loam	Loam	Silt loam	Silt loam	Loam	Loam	Loam	Loam	Loam	
Land use	Pasture, fallow	Pasture, fallow	Reforest., pasture	Reforest.	Fallow, potato (irrigated)	Reforest., fallow (potato)	Fallow	Natural vegetation, reforest.	Fallow	Maize, potato	Maize
Erosion features	Toppling	Toppling, sheet	Sheet, land slide	Sheet, gully (vegetated)	Gully (vegetated)	Sheet	Sheet, gully (vegetated)	Sheet, toppling	Sheet	Sheet	Sheet
SWC practices	Infiltr.d.	Infiltr.d.	Infiltr.d.		Infiltr.d., slow-form. terraces	Infiltr.d., bench terraces	Bench terraces (potato)	Infiltr. ditches (reforest.)	Bench terraces	Bench terraces, infiltr.d.	Bench terraces
State SWC	Neglected	Regular	Abandoned		Regular	Neglected	Regular	Good (new)	Regular	Regular	Regular
Remarks	At start dense soil cover	Some stones, irrig. canal	Stones	Shallow soils, many stones; irrig. canal	Terraces in potato fields	Infiltr.d. in reforest. area are new	Irrigation canal	Many small footpaths	Abandoned house, with eucalyptus	House	Many maize fields

General remarks: all terraces are installed on agricultural fields; infiltration ditches are found on pasture land and within the eucalyptus reforestation, sometimes also on agricultural fields in combination with terraces.

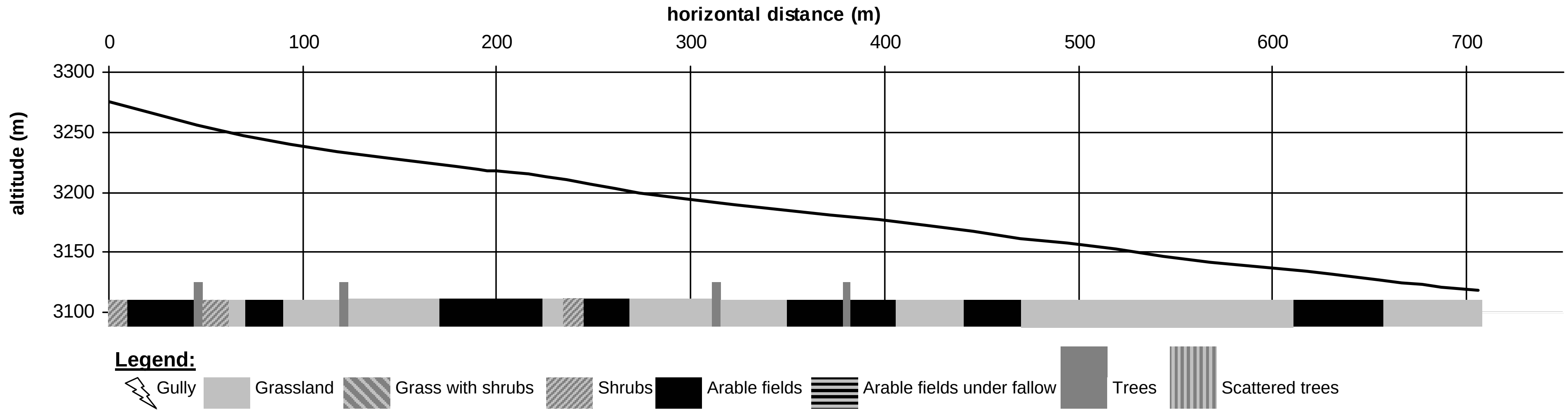
Transect 2 Community of Tahuantinsuyo (starting point: S13°36.977’, W073°17.290’; ending point: S13°36.670’, W073°17.489’)



Vegetation	Grasses	Grasses	Grasses, cactus, shrubs	Grasses, herbs	Grasses, herbs	Crop residues	Crop residues	Crop residues
Soil cover	40 – 60%	35 – 70 %	50 – 70 %	40 – 50%	40 – 50 %	50 – 60 %	50 – 60 %	
Max. slope	30 %	45 %	35 %	35 %	40 %	40 %	30 %	25 %
Slope transect	15 – 30 %	45 %	25 – 30 %	20 – 30 %	20 – 35 %	20 – 35 %	20 – 25 %	20 %
Soil texture	Silt loam	Silt loam – loamy sand	Silt loam	Silt loam	Loamy sand	Loam	Loam	Silt loam
Land use	Pasture, wheat	Wheat, fallow	Fallow, wheat	Barley, fallow	Fallow, wheat, beans	Fallow, tarhui, barley, beans, wheat	Wheat, barley, maize	Maize
Erosion features	Sheet erosion	Sheet, land slide / gully	Some sheet, some rill	Sheet erosion, gully, rills	Not identifiable	Not identifiable	Not identifiable	None
SWC measures	Infiltration ditches				Bench terraces, infiltration ditches	Bench terraces		
State SWC	Regular				Good	good		
Remarks	Waiting for rains to sow wheat	Many crop residues, stony soils	Stones		Many stones; irrigation canals, but no water	Many stones (30% of soil cover)	Many stones; at lower parts maize with irrigation.	Irrigation

General remarks: all terraces are in agricultural fields; infiltration ditches are found in pasture land. This zone is very dry. There is spare vegetation, soils contain many stones. The bench terraces belong to one farmer, who continues constructing new terraces. He states that he can only cultivate on terraces, as stones are removed and water is better retained. Unfortunately, no irrigation can be applied here.

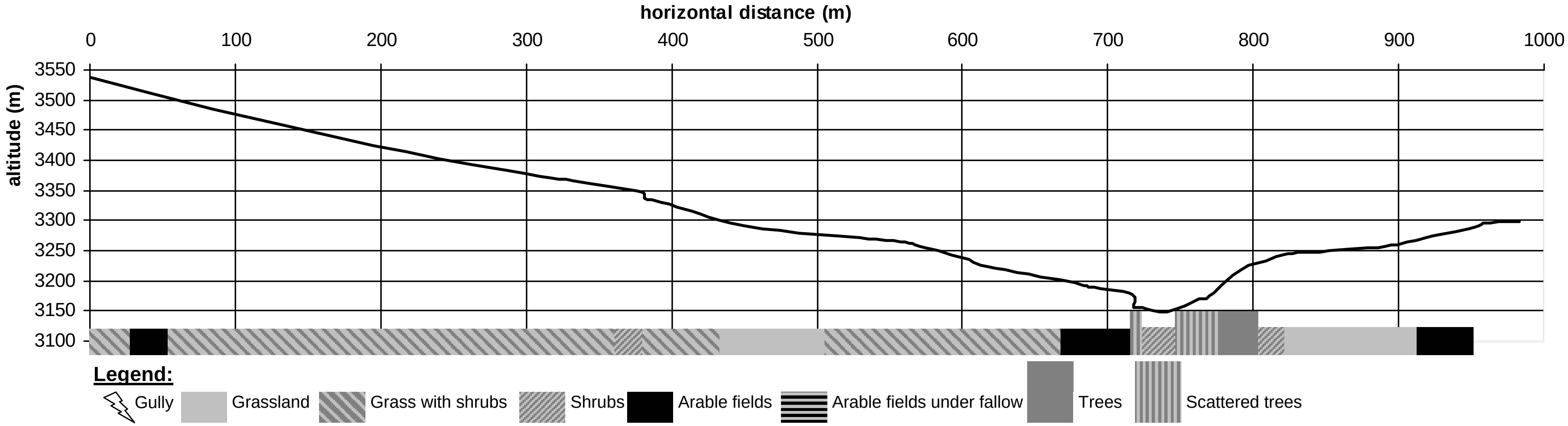
Transect 3 Community of Ancco Pachana (starting point: S13°35.691', W073°18.223'; ending point: S13°36.052', W073°18.364')



Vegetation	Grasses, shrubs	Grasses	Grasses	Grasses	Grasses	Grasses	Grasses
Soil cover	30 – 90%	20 – 90 %	25 – 100 %	20 – 95%	20 – 100 %	100 %	50 – 100 %
Max. slope	45 %	25 %	27 %	20 %	23 %	22 %	20 %
Slope transect	30 – 45 %	20 – 25 %	18 – 27 %	17 – 20 %	17 – 23 %	16 – 22 %	15 – 20 %
Soil texture			Loam				
Land use	Fallow (cereals)	Pasture, fallow (cereals)	Fallow (cereals), pasture	Pasture, fallow (potato)	Fallow (potato, maize), pasture	Pasture	Pasture, fallow
Erosion features	Not identifiable (soil was recently ploughed)	None	Not identifiable / none	Not identifiable / none	Not identifiable / none	None	Not identifiable / none
SWC practices							
State SWC							
Remarks		Stones (10% of soil cover)			Some stones (5% of soil cover)		

General remarks: in this community, no SWC-oriented programme is present. As it is not a recognized peasant community, land ownership is private. Field boundaries are well defined by the planting of eucalyptus and shrubs at the borders. No mechanical SWC practices are found, but no erosion features are found either. Soils are either densely covered with grasses, or recently ploughed. Slopes are gentle. The dense vegetation indicates that at this slope more water is available. Due to the dense soil cover, and lack of material, it is difficult to determine the soil texture. Eucalyptus trees and shrubs are also found along the footpaths.

Transect 4 Community of Santa Elena (starting point: S13°35.174’, W073°19.430’; ending point: S13°35.720’, W073°19.285’)



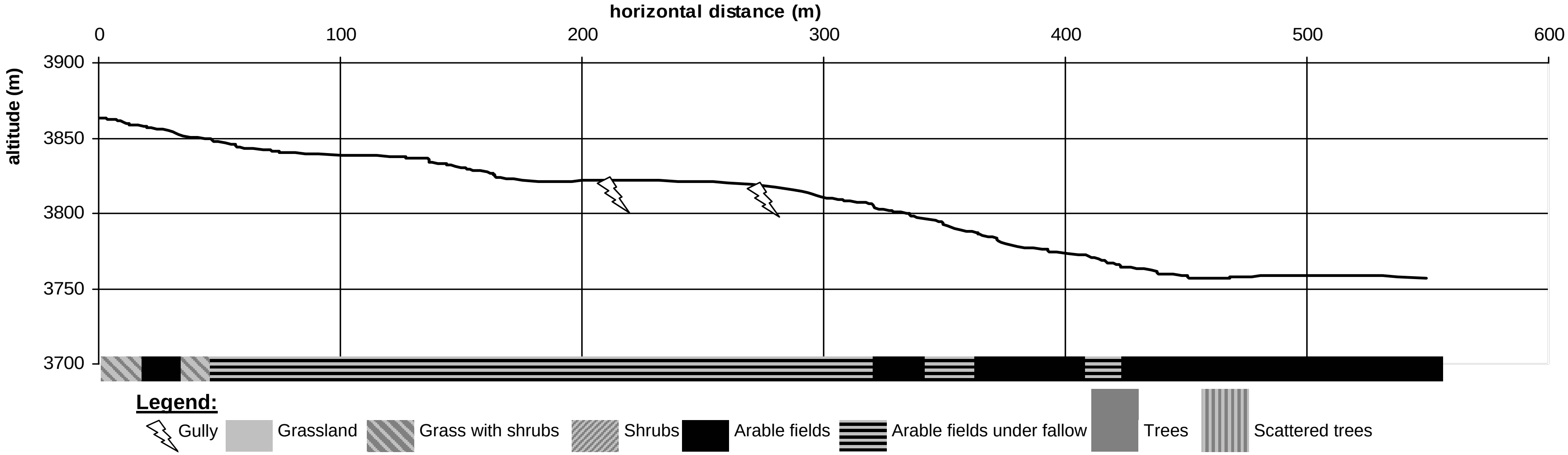
Vegetation	Grasses, shrubs	Grasses, herbs, shrubs	Grasses, herbs, shrubs	Grasses, herbs, shrubs	Grasses, shrubs	Grasses, herbs, shrubs	Grasses, shrubs	Grasses, shrubs, eucalyptus	Grasses, shrubs	Grasses
Soil cover	5 – 95 %	80 – 85 %	70 – 85 %	50 – 95 %	50 – 80 %	80 – 100 %	25 – 100 %	25 – 90 %	80 – 90 %	10 – 95 %
Max. slope	63 %	57 %	50 %	50 %	70 %	70%	85 %	200 %	79 %	55 %
Slope transect	58 – 63 %	50 – 57 %	35 – 50 %	33 – 50 %	37 – 70 %	20 – 70%	30 – 85 %	43 – 200 %	17 – 79 %	15 – 55 %
Soil texture	Silt loam		Silt loam				Loam		Loam	
Land use	Potato, pasture	Pasture	Pasture	Pasture	Pasture	Pasture	Pasture, maize, beans	Natural vegetation	Pasture	Fallow (wheat), pasture
Erosion features	Toppling, ‘cracking’, risk of land slides	Toppling / crawling	Toppling / crawling	none	none	none	None / not identifiable	Not identifiable	Crawling, land slides	Crawling, land slides
SWC practices	Infiltration ditches							Bench terraces		
State SWC	Regular							Good		
Remarks	Soil is very unstable	Soil is very unstable	Soil is very unstable	Soil is very unstable				Very steep slope	Soil slides downwards	

General remarks: the whole slope is susceptible for land slides. Apparently the cohesion of the soil is very low, and the soil is crawling down.

APPENDIX 4.2

Transects in Piuray-Ccorimarca

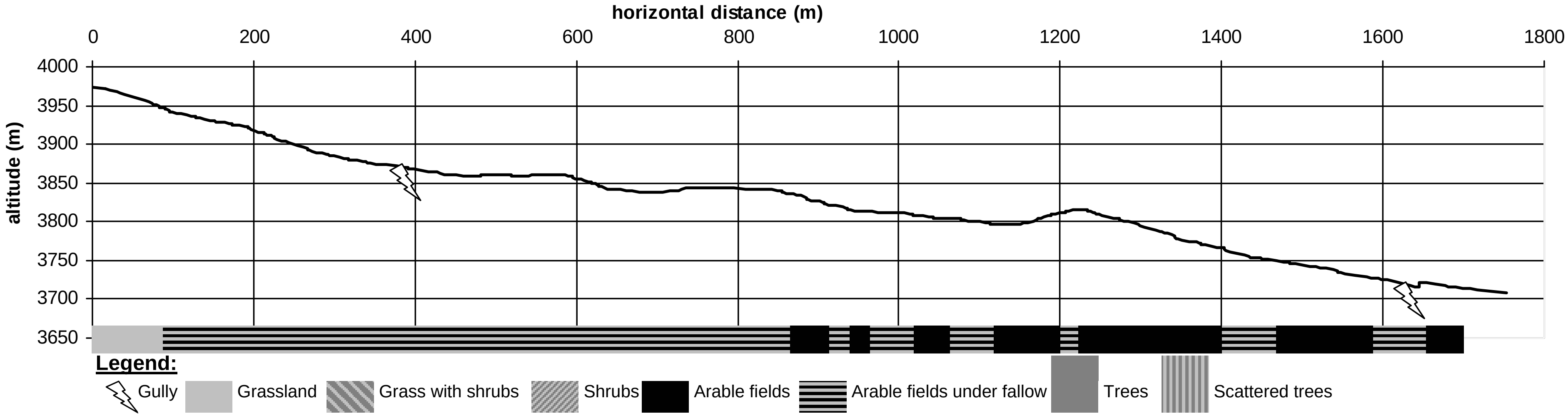
Transect 1 Community of Cuper Bajo (starting point: S13°24.342’, W072°00.891’; ending point: S13°24.515’, W072°01.067’)



Vegetation	Grasses, herbs, shrubs	Grasses	Grasses, herbs	Grasses, herbs		
Soil cover	10 – 50 %	30 – 50 %	15 – 25%	10 – 20 %	0 – 30 %	0 – 30 %
Max. slope	25 %	30 %	50 %	60 %	20 %	10 %
Slope transect	5 – 25 %	5 – 30 %	5 – 50 %	15 – 60 %	3 – 20 %	0 – 10 %
Soil texture	Loamy sand			Loamy sand		
Land use	Fallow (wheat / barley)	Fallow / pasture	Fallow / pasture	Fallow / pasture, potato	Fallow, potato	Potato, beans
Erosion features	Not identifiable	Not identifiable	Rill erosion, gullies in surroundings	Sheet erosion	Not identifiable	Not identifiable
SWC practices	Terraces formed over time; infiltration ditches	Terraces formed over time	Infiltration ditches, terraces formed over time	Terraces formed over time	Infiltration ditches; terraces formed over time	
State SWC	Neglected – regular	Regular	Regular	Regular	Regular	
Remarks	At the upper part laterite,		Laterite		Tillage perpendicular to contour lines	Tillage perpendicular to contour lines

General remarks: the terraces on these slopes seem to be formed ‘naturally’ (so-called *pata pata*), and reinforced later. Often shrubs grow on the banks. The upper part of the slope is under fallow for five years in total and is now used for pasture. Considering the type of vegetation, this part is fallow for two or three years now. After these five years, farmers will start cultivating again and terraces will be rehabilitated. These soils are very susceptible for rill and gully erosion. Also, they contain a lot of laterite.

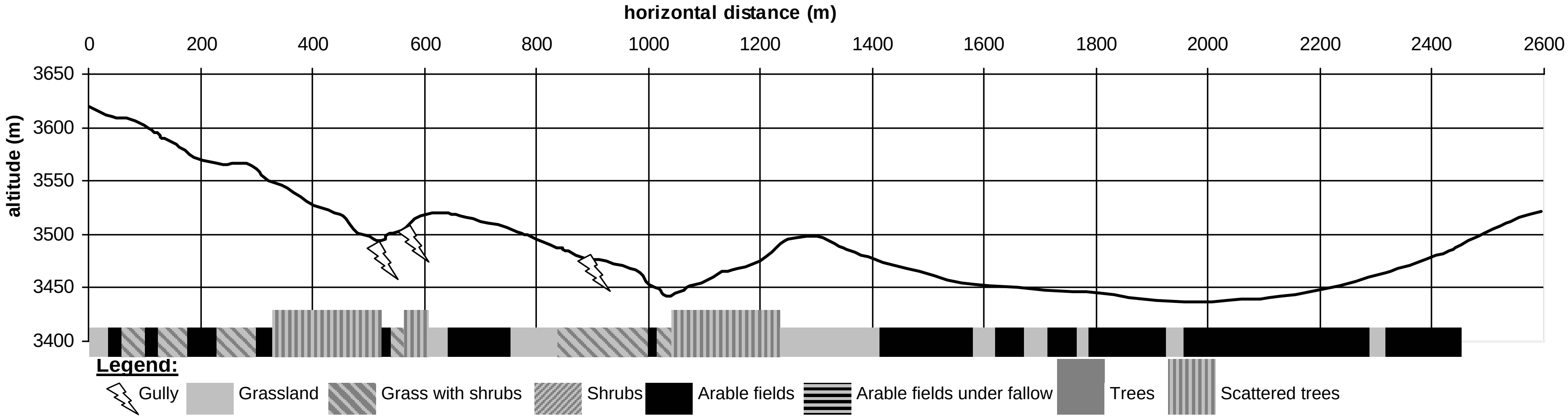
Transect 2 Community of Cuper Alto (starting point: S13°23.684', W072°02.178'; ending point: S13°24.464', W072°02.720')



Vegetation	Grasses, herbs	Grasses, herbs	Grasses, herbs	Grasses, herbs	Grasses, herbs	Grasses, herbs	Grasses, herbs	Grasses, herbs	Grasses
Soil cover	50 – 60%	10 – 80 %	30 – 80 %	40 – 80 %	10 – 90%	0 – 80 %	0 – 50 %	0 – 80 %	5 – 100 %
Max. slope	40 %	30 %	20 %	25 %	20 %	25 %	30 %	25 %	20 %
Slope transect	10 – 35 %	5 – 30 %	5 – 15 %	0 – 25 %	5 – 20 %	5 – 25 %	5 – 30 %	10 – 25 %	10 – 20 %
Soil texture	Loamy sand – loam	Silt loam	Silt loam		Loam		Silt loam – loam	Loam	
Land use	Pasture, fallow (cereals)	Fallow (cereals)	Fallow (cereals)	Fallow (cereals, beans)	Fallow (cereals), barley	Fallow (cereals), barley / wheat	Fallow (cereals), barley, potato	Fallow, potato	Fallow, pasture, potato
Erosion features	Sheet erosion	Sheet erosion, crusting, rills	Sheet erosion, crusting	Not identifiable		Sheet erosion, crusting	Sheet erosion, crusting	Crusting	Not identifiable
SWC practices	Infiltr.d.; terraces formed within time	Infiltr.d. ; terraces formed within time	Infiltr.d.; terraces formed within time	Infiltr.d.; terraces formed within time	Infiltr.d.; terraces formed within time	Infiltr. d.; terraces formed within time	Infiltr.d., terraces formed within time	Infiltr.d.; terraces formed within time	Infiltration ditches
State SWC	Neglected	Neglected	Neglected	Neglected	Neglected	Neglected / abandoned	Regular / neglected	Neglected / abandoned	Regular / neglected
Remarks	Many stones (till 30% of soil cover)	Traces of contour ploughing	Traces of contour ploughing	Many scattered fields with different management		Traces of few abandoned infiltration ditches	Scattered maintenance of SWC practices	Contour ploughing	

General remarks: as fields with different owners are scattered along the slope, management is also different. In some fields infiltration ditches are well maintained, while in neighbouring fields they are neglected or even removed. The upper part of the slope is under fallow since about 2 years.

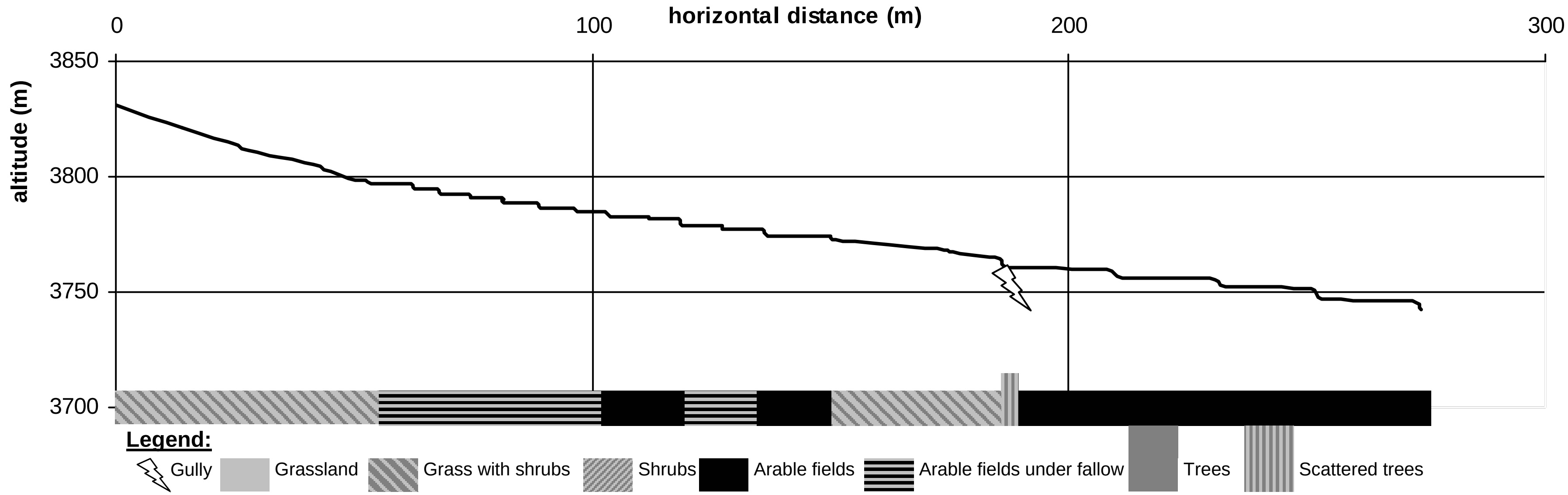
Transect 3 Community of Tangabamba (starting point: S13°26.488', W072°04.698'; ending point: S13°27.858', W072°05.039')



Vegetation	Grasses, shrubs	Grasses, shrubs, eucalyptus	Grasses, shrubs, eucalyptus	Grasses	Grasses, shrubs	Grasses, shrubs, eucalyptus	Grasses, eucalyptus	Grasses	Grasses	Grasses	Arable	Grasses	Grasses
Soil cover	35 – 90 %	30 – 90 %	30 – 90 %	15 – 80 %	5 – 70 %	5 – 90 %	60 – 90 %	20 – 90 %	20–100 %	20–100 %	10 – 40 %	20 – 80 %	20 – 70 %
Max. slope	35 %	50 %	85 %	30 %	85 %	50 %	45 %	25 %	10 %	15 %	10 %	20 %	30 %
Slope transect	3 – 33 %	10 – 50 %	15 – 85 %	5 – 20 %	5 – 65 %	15 – 50 %	5 – 45 %	5 – 20 %	5 %	5 %	5 %	5 – 20 %	20 – 30 %
Soil texture	Loam	Loam	Loam	Loam				Loam	Clay loam		Clay loam		Silt loam
Land use	Pasture, fallow, barley	Potato, reforest.	Reforest., potato	Potato, pasture	Natural vegetation, pasture	Natural vegetation, reforest.	Reforest., pasture	Pasture, cereals	Pasture, cereals	Cereals, pasture	Cereals	Cereals	Cereals, fallow
Erosion features	Sheet erosion, crusting	Not identifiable	Crusting, landslide, gully	Crusting	Some severe sheet erosion	Sheet erosion	None	None, not identifiable	None, not identifiable	None, not identifiable	None, not identifiable	None, not identifiable	None, not identifiable
SWC practices				Infiltration ditches	Infiltration ditches								
State SWC				Regular	Regular								
Remarks	Contour ploughing							Tillage with tractor	Tillage with tractor	Bad drainage	Bad drainage		

General remarks: at small scale it is difficult to recognize erosion features. But at larger scale, one can clearly see that slopes are eroded, as landslides and gullies are visible. At the valley bottom, farmers complain about problems with waterlogging due to bad drainage.

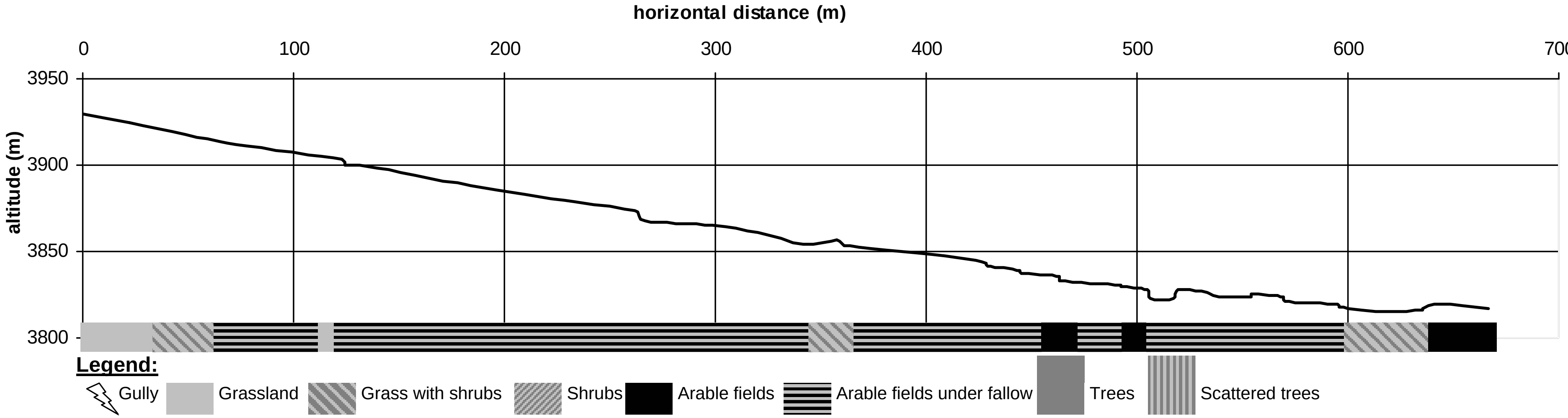
Transect 4 Community of Pongobamba (starting point: S13°25.550', W072°01.184'; ending point: S13°25.459', W072°01.306')



Vegetation	Grasses, shrubs	Grasses, shrubs	Potato
Soil cover	30 – 90 %	10 – 90 %	20 – 90 %
Max. slope	70 %	25 %	5 %
Slope transect	0 – 70 %	0 – 25 %	5 %
Soil texture	Loamy sand – silt loam	Silt loam – loam	Loam
Land use	Pasture, fallow	Fallow, potato	Potato
Erosion features	Sheet erosion	Gully	
SWC practices	Ancient terraces	Rehabilitated ancient terraces	Rehabilitated ancient terraces
State SWC	Abandoned, regular	Regular	Well maintained
Remarks			Use of irrigation

General remarks: on the slopes in Pongobamba, the ancient Inca terraces, the *andenes*, are rehabilitated for a large part. Crops are cultivated on the well maintained ancient terraces with access to irrigation.

Transect 5 Community of Umasbamba (starting point: S13°25.084', W071°59.593'; ending point: S13°25.134', W071°59.968')



Vegetation	Grasses, herbs, shrubs	Grasses	Grasses, herbs	Grasses, herbs	Grasses	Grasses	Grasses, herbs
Soil cover	70 – 90 %	30 – 50 %	50 – 80%	10 – 20 %	10 – 80 %	10 – 80 %	30 – 90 %
Max. slope	40 %	30 %	50 %	110 %	40 %	50 %	25 %
Slope transect	20 – 25 %	5 – 30 %	10 – 35 %	15 – 110 %	10 – 20 %	10 – 50 %	10 – 25 %
Soil texture		Silt loam	Loam	Loamy sand	Clay loam		
Land use	Pasture, fallow	Fallow	Fallow	Fallow, pasture	Fallow, potato	Fallow	Potato, cereals
Erosion features	Not identifiable	Not identifiable		Crawling	Not identifiable		Not identifiable
SWC practices	Infiltration ditches	Infiltration ditches, slow forming terraces, bench terraces	Infiltration ditches, bench terraces	Bench terraces	Infiltration ditches; bench terraces	Bench terraces	
State SWC	Regular, neglected	Regular, neglected	Regular, neglected	Regular	Regular		
Remarks							Irrigation

General remarks: the soils contain many stones. Most fields are fallow since 2 or 3 years.

APPENDIX 4.3

Overview of SWC practices in research areas

SWC practice	*What*	*Where*	*Who*	PRONAMACHCS	MARENASS	*Benefit*	*Costs*	*Remarks*
Bench terrace	(Stepwise) terrace with horizontal platforms and banks made of stones or earth. Some have an inward or outward inclination. High amounts of earth and stones have to be moved.	Lower parts of slope where irrigation is applied, gentle slope, reasonable soil depth.	Households with sufficient labour or working in ayni groups.	Installs these terraces at lower parts with gentle slopes and sufficient soil depth.	These terraces are preferred by farmers because enable intensification of agricultural production (two harvests per year) and yield increase.	Yield increase, but probably only in combination with irrigation and (organic) fertilisers.	Needs large investment of labour for construction and maintenance.	
Slow forming terrace	An embankment of earth or stones is made at regular interval along the contour line. Downslope, an infiltration ditch is made. A terrace is formed over time, as the soil settles upstream the embankment. The embankment should be raised now and then. No soil movement by humans needed.	Often at middle part of slope; gentle to steep slope. Sufficient soil depth is necessary.	Anyone.	Installs these terraces at middle to upper middle part of slopes.	Only few farmers install these terraces. Probably not enough benefits, and fields need large size.	Increased soil moisture content because of water harvesting effect. Benefits on very long-term.	Low investment of labour. Often not sufficiently maintained.	
Infiltration ditches	Ditches of 0.6 by 0.4 by 2 meter. Is meant to store runoff water.	At upper part of slopes, often in pasture land or reforestation areas.	Community work.	Installs the ditches on community land (pasture, reforestation), but also in combination with terraces.	Less applied, as farmers are working less on upper part of slopes. Sometimes in combination with reforestation.	Reducing runoff, increase of soil humidity.	Low investment of labour.	
Compost / worm humus	Processed domestic garbage and manure.	Used on most productive fields near farm.	Mainly applied by participants of MARENASS.		Provides extension in preparing compost and humus.	Increased soil fertility and production.	Labour costs for preparation. Collection of manure.	This practice gives benefits on short-term. Is adopted on large scale by participants of MARENASS.
Tree planting	Afforestation of degraded slopes, mainly with eucalyptus and pine.	Degraded slopes with shallow soils.	Community.	Reforestation with main objective SWC.	Reforestation with objective of SWC and firewood stock.	Firewood.		Trees are suitable for effective SWC, but possibilities are limited because of altitude.

APPENDIX 4.4

Overview of incentives for SWC practices in research areas

Type of incentive			*What*	*For whom*	*Advantage*	*Disadvantage*
Induced by programmes	Direct incentives	Tools for work	According to presence and amount of labour delivered during programme activities, a farm household receives a certain amount of tools from PRONAMACHCS.	Poor farm households.	Farmers do not have to buy tools they need for installing SWC practices. Large group of farmers is reached.	Farmers do not always need the tools they receive. It creates expectancy among farmers; whenever a programme wants to work with them, they expect to receive some direct incentives.
		Food for work	According to the presence and the amount of labour delivered during programme activities, a farm household receives food from PRONAMACHCS.	Families with small children, households in remote areas, poor farm households.	Most children do not get enough vitamins and proteins. When specific food is given, this problem can be solved. Large group of farmers is reached.	When common food is distributed, this can distort the local food production and market. Dependency is created, as well as expectancy (see above).
		Farmer competitions	MARENASS organizes competitions among farmers and communities; the group who implemented most new technologies wins a cheque (money).	Innovators, leaders; farmers who have more assets and are willing to innovate and develop.	Competition stimulates the enthusiasm of farmers to participate and to implement new techniques properly.	Some farmers consider this rewarding system unfair. Those who did their best, but have less household labour available, do not receive anything. The “laggards” and uninterested farmers are not reached.
		Cash payment	ARARIWA paid farmers for the labour they provided when installing SWC practices.	For areas where off-farm employment possibilities are scarce. All farmers are interested in extra income.	Farmers can obtain extra income. It is seen as an opportunity for off-farm activity. Large group of farmers is reached.	Farmers participate for the money they can earn, not because they think the SWC practices are important.
		Extension / training	Farmers are trained in new technologies.	Those who are keen to learn new technologies. Mostly farmers with some education and “who like being farmers”.	Farmers learn why certain activities are proposed, and how they can implement them.	Takes a lot of time and effort. The “laggards” and uninterested farmers are not reached.
	Indirect incentives	Improvement farming practices	MARENASS integrates SWC activities with other themes, like improvement of livestock, housing, common pasture land and irrigation systems.	Innovators, “leaders”, farmers eager to learn.	Farmers often do not prioritise SWC. They might decide to participate in the programme because they want to improve their livestock, and then learn also about SWC. Furthermore, increased income from agricultural activities enables them to invest in SWC.	Lot of knowledge and trainings on various themes has to be easily accessible for farmers.
Market		Increased output	Some technologies increase the agricultural output.	All who produce for own consumption and/or for the market.	Higher yields, more production.	
		Facilitate access to markets	When marketing of agricultural products becomes more interesting, farmers will be keener to intensify and increase their production.	All who produce for the market.	Lower transaction costs, facilitating marketing of products.	Needs high investments by government in infrastructure.

Chapter 5

Effects of bench terraces on soil productivity

A revised version of this chapter is presented at the *IX Congreso Nacional y II Internacional de la Ciencia del Suelo: "El Suelo: Manejo Integrado de Recursos Naturales"; Cusco, 15-19 Noviembre 2004.*
An abstract is published as: H. Posthumus (2004) El impacto de terrazas de absorción en la productividad del suelo. In: J. Alegre, M.S. Braulio y M. Ara. *El Suelo: Manejo Integrado de Recursos Naturales.* Memorias del IX Congreso Nacional y II Internacional de la Ciencia del Suelo. 15-19 Noviembre 2004, Cusco. UNSAAC, UNALM. p127.

5 Effects of bench terraces on soil productivity

There exists a general consensus that soil erosion threatens agricultural production worldwide. The rate of erosion is influenced by the slope of the land, soil composition, vegetation cover, climate and management practices, whereas soil depth, soil biota, organic matter, water-holding capacity and nutrient level influence the soil's productive capacity (Pimentel, 1993). Soil erosion reduces the soil productivity by adversely affecting these soil properties; for example, by decreasing the soil depth and plant available water capacity, removing valuable nutrients and altering soil physical properties (Enters, 1998). The purpose of soil and water conservation (SWC) practices is to maintain and increase the soil productivity by combating soil erosion. However, quantitative assessment of the effect of soil erosion or SWC practices on soil productivity is very difficult, as discussed in section 2.1. Each of the above-mentioned factors not only influences soil productivity separately, but also interacts with the other factors (Pimentel, 1993). Furthermore, these processes are location and time-specific. Besides maintaining the soil productivity, SWC practices also conserve water on the field by reducing the runoff. Often, this aspect is important for the farmers (see section 2.1), as runoff reduction is easier to perceive in the field than the conservation of soil productivity which is a long-term process. Though fully aware of this complex system of soil productivity, in this chapter the effect of SWC practices is determined by measuring soil properties and maize production on bench terraces and sloping fields in the sub-watershed Pacucha, Peru.

5.1 Materials and methods

Erosion affects the soil by selectively removing soil particles. The soil quality decreases due to loss of nutrients and degradation of the soil structure. The following measurements were carried out in order to analyse differences in soil characteristics between soils with and without SWC practices on sloping fields: infiltration measurements, soil analysis and yield measurements.

Measuring infiltration rates

The implementation of bench terraces might have an immediate effect on soil properties, as the soil is disturbed during the construction. In order to compare the infiltration capacity between bench terraces and sloping fields, a mini rainfall simulator (www.eijkelkamp.com) was used. The mini rainfall simulator is a small portable rainfall simulator for the use in the field. The rainfall simulator consists of three parts (see Figure 5.1):

1. A sprinkler (A) with a built-in pressure regulator for the production of the standard rain shower.
2. An adjustable support (B) for the sprinkler.
3. A ground frame (C), which is placed on the soil and prevents the lateral movement of water from the test plot to the surrounding soil.

The runoff plot of the rainfall simulator covers an area of 0.0625 m^2 and is surrounded with a metal frame so that all runoff water is collected at the lowest point. The rainfall intensity produced by the rainfall simulator was about 6 mm min^{-1}. This high intensity is needed to compensate for the short falling distance, in order to obtain a realistic kinetic energy of the rain drops. Though the practical use of the absolute values of these measurements is disputable, the results are useful for comparing the infiltration rates of different sites.

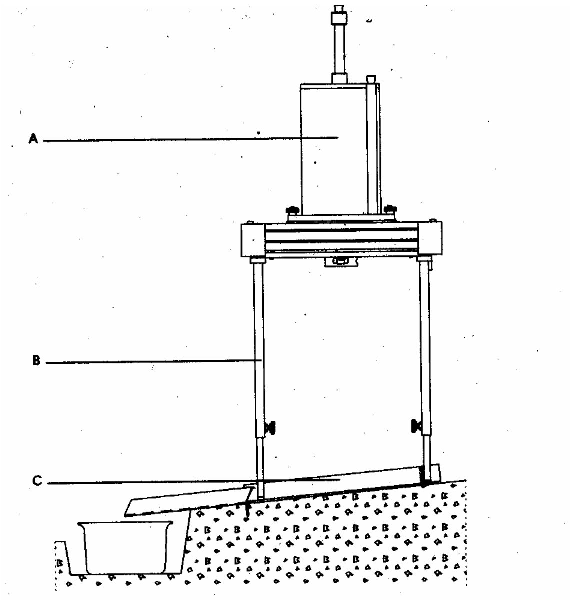


Figure 5.1 Elements of the portable rainfall simulator

Ten sites, or five pairs of existing bench terraces and accompanying sloping fields, were selected in 2002. On each site, three up to seven infiltration measurements were carried out using the rainfall simulator. The amount of repetitions depended on the variability of the infiltration measurements. Though the platforms of bench terraces are horizontal, it was impossible to find horizontal spots for the infiltration measurements, as farmers make ridges on the platforms for crop cultivation. Therefore, the runoff plot was installed on the side of the ridges, causing an inclination. However, the simulations on the terraces were still under a smaller inclination than on the sloping fields.

One simulation run took 5 minutes, and then the sprinkler had to be refilled. A simulation was executed until a constant runoff rate was reached. As a consequence, most simulations took about 20 to 30 minutes. During the simulation, the amount of runoff was measured every minute starting from the moment that runoff occurred. The infiltration rate was determined by distracting the runoff rate from the rainfall intensity. The measurements were carried out during the dry season and thus on a dry soil. However, two weeks of rainfall disturbed the measurements and therefore the measurements on the bench terraces of site 3 were carried out on a humid soil.

Soil fertility

Soil samples were collected in order to determine the soil fertility and soil texture. In 2002 soil samples were collected on the same sites where the infiltration measurements had taken place, resulting in 10 samples. In 2003, soil samples were collected for each site where maize yields were measured, at 32 different locations in total. A few samples were collected in the valley bottom as well for comparison, as these soils are supposed to be the most fertile. All soil samples were collected at a soil depth of 5 to 10 cm. The soil samples were analysed in the laboratory of the Agricultural University La Molina in Lima, Peru. Texture, organic matter content, and the quantities of total nitrogen (N), phosphate (P) and potassium (K) were determined.

Yield measurements as a proxy for soil productivity

Despite its limitations, crop yields are still frequently used as indicators for soil productivity, as the main product of the soil in agriculture is, of course, the crop yield. Crop yield is only a good estimator of the difference in productivity between two soils when: (a) the same crop is used; (b) this crop is 'optimal' for both soils; (c) all non-soil factors affecting crop yield are held constant for the situation in which yield is measured (Rijsberman and Wolman, 1984). As farmers are most concerned about decreasing crop yields, the concept of erosion-induced productivity loss (section 2.1) is used for the analysis by measuring crop yields (Erenstein, 1999; Stocking and Clark, 1999).

Maize was chosen as crop for the yield measurements, as it appeared that this crop was most extensively sown on both bench terraces and sloping fields during the rainy season. During the measurements it appeared that three different maize varieties were sown: Almidon, Morocho and Cancha. Almidon produces the largest cobs and grains, but also needs more water and a longer growing season, and is therefore mainly sown on the flat and fertile soils at the bottom of the valleys where more water is available. Morocho is a local maize variety that produces smaller grains, but also needs less water and nutrients, and it has a shorter growing season. This variety is normally sown on the sloping fields. The yield and the demand for water and nutrients of the variety Cancha lies in between those of Almidon and Morocho. Almidon is often sold on the market, as it has the best price. Morocho and Cancha are mainly used for home consumption.

In 2002, crop yields were measured at the same 10 sites as the infiltration measurements. At each site, 3 or 4 plots of 4 m^2 were laid out randomly on the site. Care was taken that the plants within the sample plots were representative for the site. The plants were cut of just above the soil, and the maize cobs were removed. The plants were counted in order to determine the *plant density* (number of plants per m^2). The vegetative parts of the plant, i.e. the stalk and leaves, were weighed for the *plant biomass* (kg m^{-2}). The vegetative parts of Morocho were already quite dry at harvest time, but most Almidon plants were still green during the measurements. The maize cobs were weighed separately for the *grain yield* (kg m^{-2}). In order to convert the fresh weight of the grain yield into a dry weight, the local technique to desiccate the grains was applied. A sub-sample of 22 cobs were taken aside and put in the sun for several weeks in order to dry the grains. When they were completely dry, the grains were weighed again, in order to establish a conversion factor to calculate the dry weight of the grain yield. The average ratio dry weight / fresh weight of the maize cobs appeared to be 0.54, with a standard deviation of 0.04. Dividing the dry weight of the grain yield by the plant density resulted in the *plant productivity* (kg $plant^{-1}$).

Additional yield measurements were carried out in 2003, in order to have a larger sample needed for statistical analyses. Unfortunately, it was not possible to evaluate the same 10 sites as in 2002, as farmers had sown other crops, or the maize had been harvested already. In 2003, sites were selected randomly. If different maize varieties were sown at a site, these samples were considered as different observations. In total 46 observations were obtained: 22 observations were collected on bench terraces and 24 observations on sloping fields. Among these 46 observations, there were 6 pairs of observations on bench terraces and accompanying sloping fields. In 2003, two sample plots of 16 m^2 were laid out randomly for each observation. The measurements were done according to the same method as in 2002.

The yields were measured at the moment the farmer started to harvest his field. During the harvesting the farmers were interviewed about their farming practices, like sowing and harvesting date, use of fertilisers, use of irrigation, crop rotation, and ploughing equipment. Also, the size of the total cultivated field was measured as well as the slope and the altitude. In case of bench terraces, the dimensions (height, length, width and slope of terrace platform – the modified slope) were measured as well. In 2002, the soil depth could be easily measured by pushing a metal stick into the soil after the infiltration measurements when the soil was still humid. In 2003, this appeared to be quite difficult as the soil was dry. In that year, the soil depth had to be estimated for many sites.

Statistical analysis

The Analysis of Variance (ANOVA) and the Student test, or t-test, were applied to verify significant differences in infiltration rates, soil fertility and grain yields between the bench terraces and the sloping fields. The zero hypothesis that the average values of these factors are equal for bench terraces and sloping fields can be verified with these tests. The Pearson procedure is applied to define linear correlations coefficients between the factors and yields, in order to get better insight in how factors are related to each other and to the maize yield.

With the data of the rainfall simulations and the yield measurements, linear regression models were estimated in SPSS. The multiple regression model is defined as (Pindyck and Rubinfeld, 1998):

$$Y_i = \beta_1 + \beta_2 X_{2i} + \beta_3 X_{3i} + \ldots + \beta_k X_{ki} + \varepsilon \qquad [5.1]$$

where *Y* is the dependent variable, the *X*'s are the independent variables, and ε is the error term. Standardised coefficients were calculated in order to indicate the relative importance of the independent variables. Using the data of the rainfall simulations, a linear regression with the infiltration / rainfall ratio as dependent variable was determined stepwise by omitting insignificant variables one by one. The same procedure is followed for the regression models estimated for crop production.

5.2 Effect of bench terraces on soil properties

Infiltration and water storage

Table 5.1 shows the results of the infiltration measurements done with the portable rainfall simulator. The main difference between the bench terraces and sloping fields is obviously the slope. The zero hypothesis that the infiltration/rainfall ratios are equal for bench terraces and sloping fields is accepted (significance level is 0.713). Apparently the infiltration capacity of the soil is not affected by terracing. However, the average values of the infiltration/rainfall ratios of the 5 sloping fields are significantly different (at 0.001 level), whereas the average values of this ratio of the 5 bench terraces are not different (0.477 level). This finding shows that infiltration capacity becomes more homogenous due to terracing.

Applying a multiple linear regression analysis with the infiltration/rainfall ratio as dependent variable gives more insight into the infiltration process (Table 5.2) The significant independent variables explaining the infiltration/rainfall ratio are: soil depth, soil texture (sand fraction) and soil organic matter content. The standardised coefficients show that soil depth has the largest influence on the infiltration/rainfall ratio, followed by the soil texture and soil organic matter respectively. These three parameters are also the only significant variables determining (positively) the final infiltration rate.

Table 5.1 *Results infiltration measurements, Pacucha 2002*

Site	Bench terraces						Sloping fields					
	Mean	**1**	**2**	**3**	**4**	**5**	**Mean**	**1**	**2**	**3**	**4**	**5**
Soil texture		Loam	Loam	Clay loam	Clay loam	Clay loam		Silty clay loam	Clay loam	Loam	Clay loam	Loam
Soil organic matter (%)	2.4	3.0	3.0	2.2	2.4	1.6	2.8	2.4	2.4	3.2	3.2	2.9
Soil depth (m)	0.6	0.5	0.5	0.7	0.7	0.6	0.6	0.6	0.5	0.5	0.9	0.5
Modified slope (%)	4	1	1	7	9	2	30	12	50	45	10	35
Inclination runoff plot (%)	22	19	19	23	19	30	42	28	56	58	34	35
Intensity (mm/min)	6.2	6.1	6.2	6.1	6.6	6.3	6.3	6.1	6.1	6.0	6.6	6.6
Final infiltration rate (mm/min)	1.8	1.2	2.3	1.7	2.4	1.7	2.2	1.0	1.9	2.4	3.5	2.1
Rainfall (mm)	167	187	169	136	220	126	164	147	115	153	239	166
Runoff (mm)	81	106	73	68	85	73	73	99	61	63	53	87
Infiltration (mm)	86	80	95	68	135	54	92	47	54	90	186	80
Infiltration / rainfall ratio	0.49	0.42	0.53	0.47	0.61	0.42	0.52	0.33	0.45	0.58	0.78	0.47

Table 5.2 *Results regression analysis on infiltration/rainfall ratio, Pacucha*

Coefficients	**Coefficients**	**Sign.**	**Standardised Coefficients**
	β		Beta
Constant	-0.412	0.004	
Soil texture: % sand	0.007	0.002	0.519
Soil organic matter (%)	0.093	0.009	0.380
Soil depth (m)	0.661	0.000	0.698
Model results: Adjusted R^2 = 0.917; significance = 0.000; N=10			

Though the infiltration capacity of the soil is determined by soil depth, soil texture and soil organic matter content, it is expected that bench terraces improve the water storage due to the modification of the slope. As the terrace platforms are horizontal, ponding of excessive rainfall or irrigation water occurs instead of overland flow (runoff), and water thus has more time to infiltrate. Farmers confirmed this assumption. They stated that the soils on the bench terraces stay humid twice as long as the soils of sloping fields. Whether terracing improves the infiltration capacity or not, does not make much difference, as excessive water will infiltrate after each rainfall event, when the water is retained on the terrace platforms. As soil organic matter positively influences infiltration, it is expected that compost also improves infiltration and thus soil moisture content.

Soil fertility

Soil erosion and SWC practices might influence the amount of nutrients available in the soil. However, results of the soil samples show that the only soil characteristic that is significantly different for sloping fields, bench terraces and valley bottom, is soil depth (Table 5.3). This significance is caused by the deep soils (up to 2m) in the valley bottom. The soils of bench terraces contain slightly more phosphorus and potassium than soils of sloping fields but this difference is not significant. As terrace construction implies soil disturbance, and the bench terraces are relatively young (i.e. two to four years), the turning over of the soil during the construction might have caused this difference.

Table 5.3 *Soil properties of sloping fields and bench terraces, Pacucha*

	Valley bottom (n = 5)		**Sloping field (n = 20)**		**Bench terraces (n = 17)**		**ANOVA results**	
	Mean	*St. dev.*	Mean	*St. dev.*	Mean	*St. dev.*	*F*	*Sign.*
Soil depth (m)	1.08	*0.23*	0.47	*0.15*	0.56	*0.08*	*37.917*	*0.000*
Soil texture								
% sand	36.0	*9.4*	38.3	*9.3*	39.9	*5.5*	*0.494*	*0.614*
% loam	34.4	*3.8*	32.5	*7.1*	31.9	*6.4*	*0.286*	*0.753*
% clay	29.6	*7.1*	29.2	*7.0*	28.2	*3.7*	*0.169*	*0.845*
Soil fertility								
Organic matter (%)	3.34	*0.47*	3.24	*0.70*	3.29	*0.82*	*0.048*	*0.953*
Nitrogen (%)	0.22	*0.03*	0.20	*0.05*	0.20	*0.07*	*0.336*	*0.717*
Phosphorus (ppm)	25.4	*11.8*	23.5	*19.2*	34.1	*21.7*	*1.383*	*0.263*
Potassium (ppm)	368	*205*	370	*222*	521	*416*	*1.160*	*0.324*

5.3 Effect of bench terraces on maize production

In the years 2002 and 2003, the maize production was measured in several farmers' fields in the watershed of Pacucha, in order to determine the impact of terracing and organic fertilisers on crop production. Maize receives only organic fertilisers, either compost or manure. Appendix 5.1 shows the descriptives of all variables measured.

Effect of bench terraces on maize yield

Table 5.4 shows the results of the yield measurements for bench terraces and sloping fields. The grain yield consists of two components: plant productivity (kg grains per plant) and plant density (plants per m^2). Different sub-categories were made according to: maize variety (Morocho or Almidon); natural slope (more or less than 25%); and organic fertilisation (yes or no).

Table 5.4 *Analysis of means of crop measurements, Pacucha, 2002 and 2003*

			Plant productivity (kg $plant^{-1}$)			**Plant density (plants m^{-2})**			**Grain yield (kg m^{-2})**		
		N	*Bench terraces*	*Sloping field*	Sign.	*Bench terraces*	*Sloping field*	Sign.	*Bench terraces*	*Sloping field*	Sign.
All		46	0.08	0.08		7.3	5.5	**	0.53	0.44	
Variety	Morocho	30	0.07	0.07		8.6	5.5	**	0.56	0.39	*
	Almidon	11	0.11	0.11		4.6	5.7		0.47	0.61	
Natural slope (%)	> 25%	24	0.07	0.05		7.9	5.5	**	0.50	0.28	**
	≤ 25%	22	0.10	0.10		6.4	5.5		0.57	0.57	
Organic fertilisers	Yes	31	0.08	0.08		7.8	5.4	**	0.56	0.42	
	No	15	0.08	0.09		5.9	5.6		0.44	0.47	

Sign.: Difference between bench terraces and sloping field is significant at 0.1 (*) or 0.05 level (**)

In many cases, plant density is significantly higher on bench terraces than on sloping fields. Though on average the grain yield on bench terraces is higher than on sloping fields, this difference is not always significant. The positive effect of bench terraces on grain yield is only significant for the variety Morocho and at slopes steeper than 25%. Note that Morocho is mainly sown on the steeper slopes. Bench terraces have no effect on plant productivity. The increased grain yield is thus due to an increased plant density. Application of organic fertilisers is associated with a higher plant density on bench terraces. However, application of organic fertiliser does not result in a significant increase in grain production. A possible explanation for this is that organic fertilisers are applied on fields with lower soil organic matter content. The soil organic matter content of 'non-fertilised' fields (3.6%) is significantly higher than the soil organic matter content of fertilised fields (3.2%) at a confidence level of P = 0.06. Table 5.5 shows more details on the combined effects of fertilisers and bench terraces on maize production.

Table 5.5 *Combined effect of bench terraces and organic fertilisers, Pacucha*

	N	Grain yield (kg m^{-2})	Plant productivity (kg $plant^{-1}$)	Plant density (plants m^{-2})	Natural slope (%)	Organic matter (%)	Quantity fertilisers (kg m^{-2})
Sloping fields	24	0.44	0.080	5.5	24.8	3.2	0.31
Bench terrace	22	0.53	0.079	7.3	29.6	3.4	0.66
No fertilisers	15	0.46	0.084	5.7	21.0	3.6	0.00
Manure	14	0.48	0.080	6.3	32.0	3.3	0.67
Compost	17	0.51	0.075	6.9	28.4	3.0	0.74
Bench terrace + no fertilisers	6	0.44	0.081	5.9	22.5	3.8	0.00
Bench terrace + manure	7	0.50	0.076	7.0	35.0	3.5	0.85
Bench terrace + compost	9	0.61	0.081	8.5	30.2	3.0	0.96
Bench terrace + fertilisers	16	0.56	0.079	7.8	32.3	3.3	0.91
Sloping field + no fertilisers	9	0.47	0.086	5.6	20.0	3.5	0.00
Sloping field + manure	7	0.46	0.085	5.6	29.0	3.0	0.50
Sloping field + compost	8	0.39	0.069	5.3	26.4	3.1	0.50
Sloping field + fertilisers	15	0.42	0.077	5.4	27.6	3.1	0.50

Especially the less fertile soils and steeper slopes receive organic fertilisers; the steepest slopes receive manure, the poorest soils receive compost. Despite the fact that fertilised bench terraces have a lower soil organic matter content than non-fertilised bench terraces, the bench terraces that receive compost result in a higher grain yield. Note that bench terraces receive a higher quantity of fertilisers than sloping fields. It is thus concluded that the combination of bench terraces and composting results in an increased maize production.

Factors correlated with maize production

In order to determine the influence of various variables on maize yield, all observations (n = 46) on sloping fields and bench terraces are used for the estimation of the correlation coefficients (Table 5.6). The *grain yield* (kg m^{-2}) is linear correlated with the modified slope (-), soil depth (+), the number of crops harvested per year (+), plant density (+), plant biomass (+) and plant productivity (+). The steepness of the slope influences negatively the yield. As bench terraces modify the slope, i.e. the slope becomes less steep, bench terraces improve grain yield. Sowing two crops a year instead of one, results in higher maize yield. In general, two crops a year are sown on fields with favourable conditions. It might be that maize benefits from the fertiliser residuals that are applied to the second crop in the dry season, which is normally potato. The correlation coefficients found for grain yield on either sloping fields or bench terraces, are quite similar to the correlation coefficients for both groups combined. The grain yield on terraces is strongly correlated with plant density, while the yield on sloping fields is stronger correlated with plant productivity. The grain yield on bench terraces was lower in 2003 than in 2002.

Table 5.6 *Correlation coefficients for maize production on sloping fields and bench terraces*

Variables	Sloping fields (n=24)			Bench terraces (n=22)			All (n=46)		
	Plant density	Plant prod.	Grain yield	Plant density	Plant prod.	Grain yield	Plant density	Plant prod.	Grain yield
Year of measurement				- -		- -		+	
Natural slope (%)		- -	- -		-			- -	
Bench terrace							+		
Modified slope (%)								- -	- -
Soil organic matter (%)				-			-		
N content (%)		+		- -			- -	+	
P content (ppm)				- -	+			+	
K content (ppm)				-	+				
Soil texture: % sand					-			-	
Soil depth (m)			+ +						+ +
Growing days		+		- -	+			+ +	
Crops per year		+		+		+ +		+	+ +
Morocho		-		+	-			- -	
Almidon				-	+ +			+ +	
Plant density (plants m^{-2})			+		-	+ +			+ +
Plant biomass (kg m^{-2})		+ +	+ +	+					+ +
Plant productivity (kg $plant^{-1}$)			+ +	-					+ +

Significant at 0.01 level: + + is positive, - - is negative correlation
Significant at 0.05 level: + is positive, - is negative correlation

The grain production per plant or *plant productivity* (kg $plant^{-1}$) is correlated with variety, natural and modified slope (-), and soil characteristics like nitrogen content (+), phosphorus content (+), and sand fraction (-). Plant productivity was higher in the year 2003. Farmers confirmed that the maize performance was better in 2003 than in 2002. In 2002 there was a dry spell during the rainy season, causing crop failure. The plant productivity is also correlated with the length of the growing season. However, this might be partly explained by the fact that the length of the growing season is correlated with the maize variety: Morocho needs a shorter period to ripen than Almidon, which is known for its higher plant productivity. The crop rotation is also correlated with plant productivity. If a second crop is sown during the dry season, the plant productivity of the maize sown in the rainy season is higher. The natural slope is negatively correlated with plant productivity, even for bench terraces. The natural slope can be seen as a proxy for soil quality. In general, fields with steep slopes are poor in soil fertility and shallow in soil depth.

Plant density (plants m^{-2}) is correlated with: bench terraces (+), modified slope (-), year of measurement (-), the nitrogen content (-), phosphorus content (-), plant biomass (+) and grain yield (+). Bench terraces enable a higher plant density, as the natural slope is modified. The plant density on bench terraces was lower in 2003 than in 2002, explaining the lower crop yield in 2003. It is not clear whether this difference has to do with the difference in sampling between the two years. It might also be that farmers decided to sow the maize less dense in 2003 to prevent crop failure as in the previous year. On bench terraces, plant density is negatively correlated with plant productivity. Possibly farmers tend to sow maize too dense on terraces, resulting in competition for soil nutrients. On the other hand, Morocho is sown on soils with low fertility, and this variety is sown very dense.

It might thus also be that low soil fertility leads to high plant densities because of the choice of maize variety. The plant density on sloping fields is not linear correlated with any variable.

Considering the linear correlations between the different variables and yield, a correlation diagram is drawn explaining how factors are interrelated with each other and with the grain yield (Figure 5.2). However, some variables that are not significantly correlated might still influence the maize production. The Pearson correlation only estimates the *linear* correlation, but *nonlinear* correlations are ignored. More linear correlations are estimated between variables, but in order to keep the picture orderly, some less relevant correlations are left out.

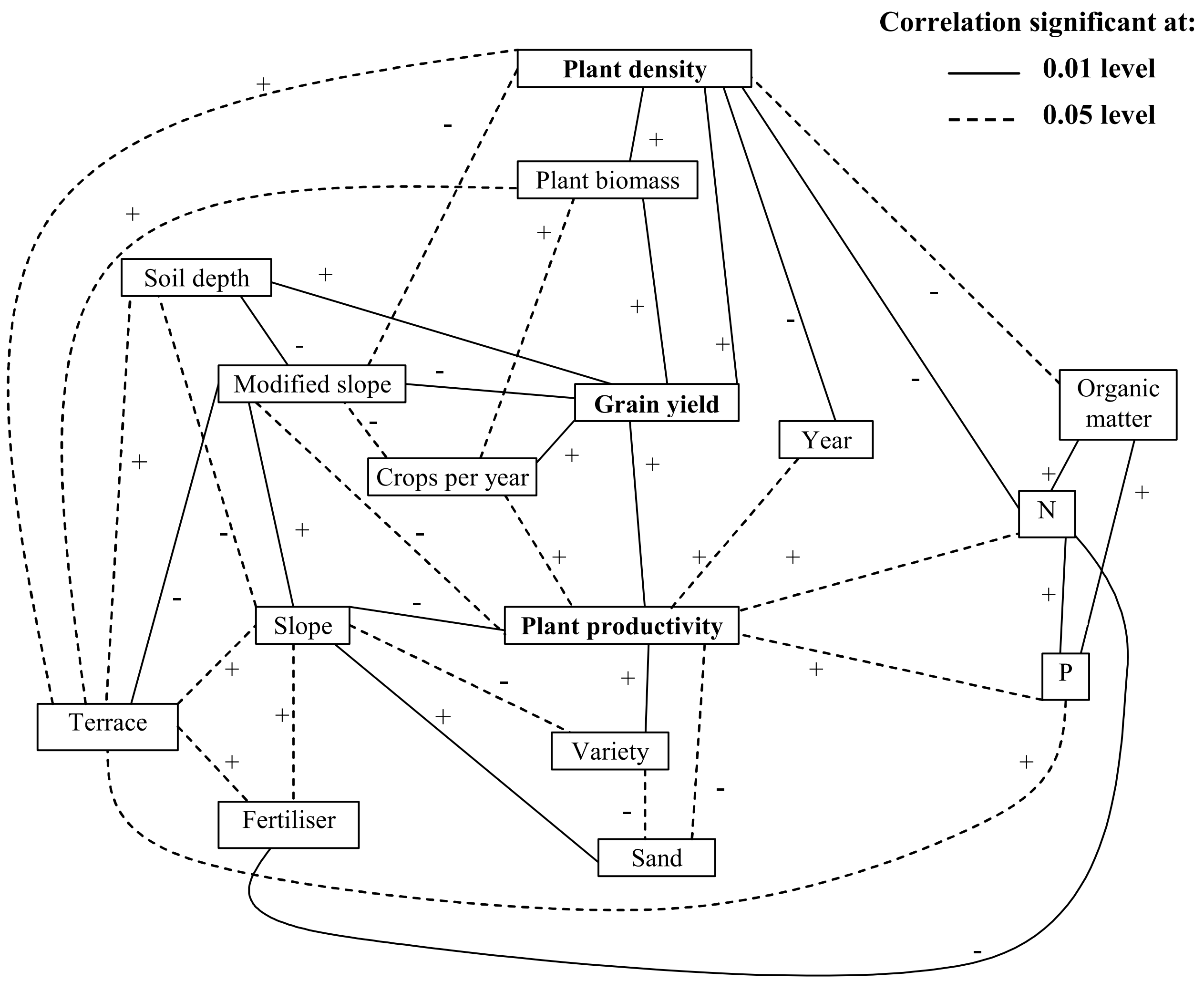


Figure 5.2 Factors influencing maize production

The correlations suggest that an increased plant density leads to a decrease in soil nutrients, and thus a decrease in plant productivity. This means that if the implementation of bench terraces results in an increased plant density, this has be combined with fertilisers to prevent a decrease in soil nutrients and a decrease in soil and plant productivity. Bench terraces have a direct positive influence on plant density and plant biomass, and an indirect influence on grain yield through the modification of the slope and soil depth. The fact that modified slope, and not natural slope, is correlated with the number of crops per year implies that bench terraces enable two harvests a year.

Linear regression models explaining maize production

The results of the linear regression models for *grain yield* (Table 5.7), *plant productivity* (Table 5.8) and *plant density* (Table 5.9) are shown below. The estimated regression models contain only the significant variables.

Table 5.7 *Results regression analysis on grain yield (kg m^{-2}), Pacucha*

Significant variables	Coefficients	Sign.	Standardised coefficients
	β		Beta
Constant	0.039	0.837	
Modified slope (%)	-0.005	0.041	-0.304
P content (ppm)	-0.003	0.036	-0.293
Soil depth (m)	0.684	0.016	0.370
Crops per year	0.196	0.022	0.314
Application of manure	0.122	0.076	0.237
Model results: Adjusted R^2 = 0.362; significance = 0.000			

The variables modified slope, soil depth and the number of crops harvested per year influence the *grain yield* (kg m^{-2}), as was already concluded in Figure 5.2. Other significant variables are phosphorus content and the application of manure. Though compost is also applied as fertiliser, this is not significant. Comparison of soil characteristics show that organic fertilisers are applied on soils with a low nitrogen (0.19%) and soil organic matter content (3.2%). The nitrogen (0.23%) and soil organic matter content (3.6%) of soils that do not receive fertilisers are significantly higher. Manure is applied on fields with high nitrogen content of 0.22%, while the fields with compost fertilisation have significant lower nitrogen content of 0.17%. Apparently, no effect of compost on grain yield can be measured, as the compost is used to compensate for the lower soil fertility.

Table 5.8 *Results regression analysis on plant productivity (kg $plant^{-1}$), Pacucha*

Significant variables	Coefficients	Sign.	Standardised coefficients
	β		Beta
(Constant)	0.053	0.051	
Natural slope (%)	-0.001	0.006	-0.368
N content (ppm)	0.141	0.055	0.235
Crops per year	0.025	0.023	0.269
Quantity fertilisers (kg m^{-2})	0.017	0.029	0.262
Morocho	-0.025	0.004	-0.348
Model results: Adjusted R^2 = 0.481; Significance = 0.000			

Plant productivity (kg $plant^{-1}$) is positively determined by nitrogen content in the soil, fertilisation, and the harvest of two crops per year. The maize variety Morocho results in a lower plant productivity. Apparently, the natural slope can be seen as a proxy for the soil quality. The natural slope is negatively correlated with both soil depth and the nitrogen content. In other words, increasing steepness of the slope is associated with shallower and poorer soils. The amount of organic fertilisers applied has a positive influence on the crop productivity.

Table 5.9 *Results regression analysis on plant density (plants m^{-2}), Pacucha*

Significant variables	Coefficients	Sign.	Standardised coefficients
	β		Beta
(Constant)	10.970	0.000	
Year	-3.562	0.000	-0.576
Slope (%)	0.077	0.002	0.453
Modified slope (%)	-0.118	0.000	-0.703
P content (ppm)	-0.048	0.005	-0.375
Soil texture: % clay	-0.161	0.017	-0.332
Irrigation	1.974	0.039	0.297
Crops per year	1.865	0.027	0.268
Application of manure	1.911	0.013	0.334
Quantity fertilisers (kg m^{-2})	-1.023	0.088	-0.207
Model results: Adjusted R^2 = 0.601; Significance = 0.000			

As said before, the *plant density* (plants m^{-2}) was lower in 2003 than in 2002, which explains the negative sign for year. The steeper the slope, the denser the crop is sown. This can be partly explained by the fact that the natural slope is positively correlated with the maize variety Morocho, which is sown more densely than the other two maize varieties. Plant density is higher on the bench terraces, as the modified slope is negatively influencing the plant density in contradiction to the natural slope. It is not likely that a low phosphorus content results in a high plant density. But it might be that the phosphorus content is correlated with another variable that influences the plant density. Soil texture (clay content) is also significant. The clay fraction is negatively correlated with the natural slope, which positively influences the plant density. The negative sign for the clay fraction can thus be explained by its correlation with natural slope. Crops are sown denser at sites with access to irrigation. Though the application of manure positively influences plant density, the amount of fertilisers negatively influences plant density. This is contradicting to Table 5.5 where a higher quantity of fertilisers is correlated with higher plant density. Here the misinterpretation is probably due to multicollinearity[8]: the quantity of fertilisers is correlated with the dummy for fertiliser application and natural slope. The negative sign of the phosphorus content might also be caused by these correlations.

Yield increase and area loss due to terracing

Bench terraces modify (i.e. decrease) the slope, resulting in a yield increase. However, this yield increase is mainly caused by an increased plant density on these terraces. Plant productivity is determined by crop variety, and bench terraces have no influence on this. Though bench terraces enable an increase in plant density and thus grain yield, area is lost because of the implementation of these terraces. It is calculated that the area lost due to terracing ranges from 16 to 22 %, with an average of 20%. In the previous analyses on crop production this area loss is not taken into account. However, when the grain yields are extrapolated from one square meter to one hectare, the grain

[8] When independent variables have a high degree of multicollinearity, interpretation of the coefficients becomes difficult. A regression coefficient is interpreted to measure the change in *Y* that is due to a change in the variable in question, other things being equal. But any time a given change in one variable occurs, the corresponding observation on its highly correlated partner is likely to change in a predictably similar fashion (Pindyck and Rubinfeld, 1998)

yield and plant density have to be adjusted for the area that is lost due to terracing. Table 5.10 shows the adjusted maize production.

Table 5.10 *Analysis of means of maize yield measurements, adjusted values, Pacucha*

			Plant productivity (kg plant^{-1})			Plant density (plants ha^{-1})			Grain yield (kg ha^{-1})		
		N	*Bench terraces*	*Sloping field*	Sign.	*Bench terraces*	*Sloping field*	Sign.	*Bench terraces*	*Sloping field*	Sign.
All		46	0.08	0.08		58452	54797		4232	4419	
Variety	Morocho	30	0.07	0.07		69065	55008	*	4479	3861	
	Almidon	11	0.11	0.11		36515	57000	**	3766	6105	**
Natural slope (%)	> 25%	24	0.07	0.05		63456	54510		3991	2848	
	≤ 25%	22	0.10	0.10		51223	55040		4580	5749	
Organic fertilisers	Yes	31	0.08	0.08		62629	53988		4504	4243	
	No	15	0.08	0. 09		47313	56146		3506	4713	

Sign.*:* Difference between bench terraces and sloping field is significant at 0.1 (*) or 0.05 level (**)

When the values are adjusted for the area lost due to terracing, differences in plant density and grain yield become less significant. Any increase in plant density and/or grain yield enabled by terracing, is nullified by the loss of total area cultivated. In case of Almidon, bench terraces even result in a significant lower grain yield. However, bench terraces also enabled the cultivation of Almidon where it would not have been cultivated on the adjacent sloping fields because of unfavourable conditions.

Table 5.11 *Results regression analysis on adjusted grain yield (kg ha^{-1}), n=46*

Significant variables	Coefficients	Sign.	Standardised Coefficients
	β		Beta
(Constant)	1345	0.787	
Year	-1961	0.083	-0.386
Bench terrace	-2787	0.002	-0.643
Modified slope (%)	-102	0.003	-0.739
N content (ppm)	16108	0.065	0.431
P content (ppm)	-52	0.027	-0.496
Soil texture: % loam	-149	0.018	-0.464
Soil texture: % clay	-111	0.076	-0.280
Soil depth (m)	5988	0.077	0.354
Growing days	39	0.085	0.286
Crops per year	1508	0.070	0.264
Application of manure	1431	0.073	0.304

Model results: Adjusted R^2 = 0.414; significance = 0.001

Table 5.11 shows the results of the estimated linear regression for the adjusted values of grain yield. It is interesting to see that, when the grain yield is adjusted for the area lost due to terracing, the terracing even becomes a restricting factor for the maize production. However, the levelling of the slope through terracing still favours the grain yield. Now that the effect of terracing is reduced, other soil characteristics became more significant, like nitrogen content (+) and soil texture. Also the length of the growing season is positively influencing the grain yield. The estimations of a linear regression model for the adjusted plant density did not differ much from the estimations made in Table 5.9.

5.4 Conclusions

Infiltration measurements show that soil texture, soil organic matter and soil depth are the main determinants of infiltration capacity of the soil. Soil improvement through agronomic measures like composting and mulching thus seem to be important to reduce runoff, and as a consequence, soil erosion. In addition, it is assumed that bench terraces allow water to infiltrate over a longer time period as ponding occurs due to the levelling of the slope. Though measurements could not be carried out to prove this assumption, farmers confirm that the soil on bench terraces remains humid twice as long as the soil on sloping fields. Statistical analyses show that bench terraces enable a higher plant density (plants m^{-2}), resulting in an increased grain yield (kg m^{-2}). The plant productivity (kg $plant^{-1}$) is determined by maize variety, soil fertility and fertilisation. The effect of bench terraces on production increase is more pronounced on the fields with steeper slopes. Organic fertilisers are applied on soils with a lower nitrogen and soil organic matter content, explaining the limited effect of fertilisation on grain yield in this case study. The combination of bench terraces and organic fertilisation though, results in a significant increase of maize production.

However, the increase in crop density and, as a consequence, grain yield established through bench terraces, is nullified by the amount of area lost (20%) due to the same terracing. If the improved conditions due to the terraces are not fully exploited, bench terraces may finally result in a lower maize production. In that sense, terracing is only justified if advantage is taken of the improved conditions for agricultural production: e.g. cultivation of a second crop during the dry season or the cultivation of a cash crop with high market value. Access to irrigation is in many cases a requisite for the intensification of agriculture on bench terraces. Others also found that, in the Andes, terraces with irrigation and intensive cultivation of high value crops are maintained throughout the years, whereas less care is taken of rainfed terraces with extensive cultivation (Coolman, 1986; Rist and Martin, 1991). Furthermore, the increased soil productivity has to be combined with other means to maximise the benefits of terraces. Improved crop rotations, fertilisation, and an improved portfolio of crops linked to markets have an important part to play (Rodríguez and Nickalls, 2002).

APPENDIX 5.1

Descriptives of variables measured during yield measurements

Dependent variables	**Description**	**Mean**	**Standard deviation**
Plant density	Number of plants per m^2 (plants m^{-2})	6.4	2.67
Plant productivity	Grain quantity per plant (kg $plant^{-1}$)	0.080	0.035
Grain yield	Grain quantity per m^2 (kg m^{-2})	0.484	0.239
Independent variables			
Year of measurement	= 1 if data is measured in 2003; 0 if in 2002	0.76	0.43
Altitude	Meters above sea level (m)	3163	39.96
Natural slope	Natural slope of field (%)	27.1	15.6
Bench terrace	= 1 if site has bench terraces; 0 if not	0.48	0.505
Modified slope	Modified slope of field (%) – is equal to the natural slope in case there are no bench terraces	15.5	15.93
Soil organic matter	Soil organic matter content in soil (%)	3.30	0.736
N content	Nitrogen content in soil (%)	0.205	0.0586
P content	Phosphorus content in soil (ppm)	29.5	20.77
K content	Potassium content in soil (ppm)	442	325.6
Soil texture: sand	Sand fraction in soil texture (%)	38.7	7.72
Soil texture: clay	Clay fraction in soil texture (%)	28.8	5.51
Soil depth	Soil depth of field or terrace (m)	0.51	0.13
Growing days	Length of actual growing period of maize (days)	216	16.1
Access to irrigation	= 1 if there is access to irrigation; 0 if not	0.8	0.40
Crops per year	Amount of crops in rotation per year at same field	1.17	0.38
Fertiliser	= 1 if fertilisers are applied; 0 if not	0.67	0.47
Fertiliser: manure	= 1 if manure is applied as fertiliser; 0 if not	0.30	0.47
Fertiliser: compost	= 1 if compost is applied as fertiliser; 0 if not	0.37	0.49
Quantity fertiliser	Amount of fertiliser applied (kg m^{-2})	0.48	0.540
Variety Morocho	= 1 if maize variety is Morocho; 0 otherwise	0.65	0.48
Variety Almidon	= 1 if maize variety is Almidon; 0 otherwise	0.24	0.43

Cost-benefit analysis of bench terraces

This chapter is a revised version of:
H. Posthumus and J. de Graaff (2005) Cost-benefit analysis of bench terraces, a case study in Peru. *Land Degradation & Development 16:1-11*

6 Cost-benefit analysis of bench terraces

When inappropriate farming practices are applied in mountainous areas, there is a risk of soil erosion. A soil's vulnerability to erosion depends on how easily it is damaged (which is determined by the soil characteristics) and on how significant that damage is for crop production. In case soil erosion results in yield decrease, this can be considered a cost. When soil and water conservation (SWC) practices are implemented, soil erosion and yield decrease can be prevented, which can be considered as an avoided cost, or benefit. However, SWC practices often require a costly investment for the implementation. It then becomes important to know whether the long-term benefits of reduced soil erosion make these investment costs worth bearing (Pagiola, 1994). In this chapter, cost-benefit analysis (CBA) is applied to define the profitability of bench terraces.

6.1 Cost-benefit analysis explained

Cost-Benefit Analysis (CBA) centres on the quantification and measurement of the costs and benefits of an intervention. CBA is often used for the social appraisal of programmes (Common, 1996), and is based on applied welfare economics. It addresses the efficiency of an intervention, using a monetary approach. This implies that scores on efficiency attributes are valued in terms of money (Pelt, 1993). CBA aims at a comparison between the present value of the streams of benefits and the present value of all investment and recurrent costs of an intervention (Graaff, 1996). A distinction can be made between financial, economic and social CBA: social and economic CBA are used to determine efficiency from a society's point of view, whereas financial CBA is used for the private perspective (Davies and Richards, 1999). Social CBA takes income distribution effects into account, assuming that it is desirable to prevent the rich becoming richer and the poor poorer. Economic CBA only determines the efficiency of the intervention for society, neglecting any inequity in the distribution of the benefits (Kuyvenhoven and Mennes, 1985; Pelt, 1993).

In this case study, CBA is used to evaluate the profitability of bench terraces at field level in the Peruvian Andes. It is important to know the profitability of bench terraces from farmers' perspective, as they make the decision whether to implement terraces on their land. Another reason to study the profitability at field level is that the impact of bench terraces is highly site-specific and can thus vary within small areas (Lutz et al., 1994b; Shiferaw and Holden, 2001). The flows of costs and benefits in cases with and without bench terraces are compared in order to determine the profitability of bench terraces at field level. The remainder of this chapter will therefore focus on the application of financial CBA only.

The main steps of financial cost-benefit analysis

The following steps are defined in the CBA process (Graaff, 1996; Enters, 1998):

1. Determination of evaluation criteria.
2. Identification of effects (costs and benefits).
3. Quantification in physical terms of the effects.
4. Valuation of effects, including shadow pricing.
5. Determination of time horizon.
6. Weighing of the costs and benefits in time (discounting).
7. Sensitivity analysis.

The evaluation criteria

Several evaluation criteria can be used for financial CBA, but most common are the net present value (NPV) and the internal rate of return (IRR). The criteria NPV and IRR are explained below (based on: Dixon et al., 1988; Zerbe and Dively, 1994; Common, 1996):

The Net Present Value (NPV)

The NPV is the most widely used evaluation criterion. It determines the present value of net benefits by discounting the streams of benefits (*B*) and costs (*C*), arising between the present (time zero) and *t* time periods into the future as calculated as:

$$NPV = \sum_{t=0}^{T} \frac{B_t - C_t}{(1+r)^t} = (B_0 - C_0) + \frac{B_1 - C_1}{1+r} + \frac{B_2 - C_2}{(1+r)^2} + \ldots + \frac{B_T - C_T}{(1+r)^T} \qquad [6.1]$$

The subscripts refer to time periods and the discount rate is *r* per time period. A positive NPV favours the "with" situation over the "without" situation, as it will make the firm better off.

The Internal Rate of Return (IRR)

The IRR is the rate of return on an investment, i.e. the discount rate that would result in a zero net present value (the break-even point) of a programme. If the IRR is greater than the alternative or opportunity cost interest rate accessible to the stakeholder, it is a favourable investment. The IRR is found by an iterative process and is equivalent to the discount rate (*r*) that satisfies the following relationship:

$$\sum_{t=0}^{T} \frac{B_t - C_t}{(1+r)^t} = 0 \qquad [6.2]$$

The IRR is most useful when – as is commonly the case – the discount rate that should be used is uncertain or in dispute (Pagiola, 1994). The IRR is less useful for comparison between different interventions. Though the IRR might be higher, the absolute profit, or NPV, might be less, as the IRR is a proportional value and the absolute value of the benefits is not considered. IRR is applicable for simple cases and clear cash flows. However, a problem arises if negative cash flows occur after positive cash flows, as IRR can produce multiple solutions because of the polynomial used to calculate the IRR. This is knows as the multiple roots problem (Zerbe and Dively, 1994).

Identification of costs and benefits

Determining the costs is often a straightforward exercise, unless costs have to be divided into financial and economic costs. Identification of the benefits might be more complicated, especially when they are intangible (i.e. impossible to quantify the benefit in monetary terms), like improved water quality, impact of erosion on yield or secondary benefits to the community (Bojö, 1992). To be able to apply CBA, two requirements have to be met: 1) the impacts of the intervention are measured on a quantitative and physical scale, and 2) (shadow) prices are used to assess the value of the (physical) impact (Pelt, 1993). In this case study, costs are the investment and maintenance costs for the farmer who implements bench terraces. The benefit is the change in agricultural production.

Quantification of physical effects

The impact of SWC practices on crop yield has to be quantified before it can be valuated in economic terms. The quantification of output in the "with" and "without" situation is often the weakest part in CBA studies. The comparison of the with and without situation is difficult, as it is not always clear how farming practices affect the soil, and how soil erosion or SWC affects yields (Bojö, 1992; Pagiola, 1994). The understanding of these relationships is often limited. Even when the understanding is adequate, the ability to quantify them is minimal (Pagiola, 1994). Even though, CBA can still use the most reasonable estimates available and test whether different assumptions on this point make an important difference (Bojö, 1992). Being aware of its limitations (Pagiola, 1992), the "change of productivity approach" (Enters, 1998) is used in this case study for the quantification of the effects of bench terraces. This approach relies on crop yields with and without terraces. It is assumed that in the "with" situation yields remain constant, but that in the "without" situation erosion occurs. The erosion damage equals the value of the lost crop production.

Valuation

According to CBA, prices are the means to aggregate individual preferences (Pelt, 1993). Hence, valuation means the attachment of price tags to the costs and benefits of interventions that have been quantified. As such, the costs and benefits of an intervention are reduced to a common unit, and CBA is the forum for comparing them (Stocking and Abel, 1989). Prices used for financial CBA are normally market prices, reflecting the costs in the budgets of a farm household. However, problems may arise where there are no markets or where peasant production is not involved in the market. In that case, opportunity costs might be used as shadow prices. The changes in crop production will be valued with market prices, but for the labour costs valuation is more complicated.

In general, terrace construction requires a huge amount of labour. The amount of labour required depends on soil quality, soil depth, availability of material for bank or wall construction, humidity of the soil and the degree of mechanisation of the terrace construction (Rist and Martin, 1991). As the labour costs mainly determine the investment costs, its valuation is crucial. Stocking and Abel (1989) present several methods to valuate the extra labour required for SWC practices, depending on the circumstances:

- If SWC takes up leisure time and no other activity is reduced, opportunity cost is zero.
- If another enterprise is curtailed in order to practice soil conservation, the cost is the income to labour, which would have accrued from that enterprise.
- If off-farm work is abandoned, then similarly the cost is the amount of earnings foregone.
- If workers are employed, and there is a perfect labour market, the labour cost is their wage.

In case farm households are occasionally involved in off-farm activities, opportunity costs of labour are used. The opportunity cost of labour depends on the nature of the activity performed, the characteristics of the labourer (age, wealth and gender), the season (growing or slack season) and the availability of non-farm and off-farm employment (Enters, 1998). The opportunity cost of labour thus varies among farmers and it might be wrong to use one standard opportunity cost for all farmers in a CBA study.

Time horizon

The NPV is very sensitive to time horizons as well as to discount rates. Though many farmers want to fulfil short-term needs, it would be wrong to assume that their decision-making is guided by short-term thinking (Enters, 1998). They also make long-term investments, whether being it tree planting or financing their children's education. When executing a CBA, the time horizon should conform with the production characteristics (Enters, 1998) and the physical and/or economic lifetime (Bojö, 1992) of the technology studied.

Discount rate

The costs and benefits of a programme occur over time, forming streams of costs and benefits over the lifetime of a programme. In CBA, future costs and benefits are discounted to their present value. An appropriate discount rate is thus crucial for the calculation of NPVs. The rational for the choice of discount rate is often a "weak spot" in many cost-benefit studies and often criticised (Pelt, 1993; Enters, 1998). The choice of the discount rate should be based on two principles: time preference (of the decision maker or stakeholder) and the opportunity cost of capital. The opportunity cost of capital is based on the foregone production that results when capital is invested in one project rather than another.

Sensitivity analysis

Any CBA is based on less than perfect information regarding past and current costs and benefits, and more so regarding the uncertain future (Bojö, 1992). Sensitivity analysis is used to test the assumptions and to indicate the uncertainty of the CBA-outcome (Pelt, 1993). The sensitivity analysis is a technique calculating the quantitative effect of a unit change in a cost or benefit item on the intervention's NPV or IRR. In this way, risk and uncertainty with regard to particular costs and benefits can better be identified, and their relative importance in the overall analysis be established (Kuyvenhoven and Mennes, 1985). Sensitivity analysis helps to provide a better understanding of the critical elements on which the outcome of the intervention depends. It may focus attention on the variables for which a further effort should be made to firm up the estimates and narrow down the range of uncertainty (Squire and Tak, 1975).

6.2 Materials and methods for CBA of bench terraces

In order to determine the profitability of bench terraces, data of 11 fields of 9 different farmers were used for the cost-benefit analyses (see Table 6.1). In 2002, 5 sites were selected with each a terraced field (= "with") and an adjacent sloping field under similar conditions (= "without"). In 2003, 6 field pairs of "with" and "without" situation were selected. Yield measurements were carried out to determine the crop production (see also Chapter 5). Farmers were interviewed about their farming practices, the costs and benefits of the terraces, agricultural production and inputs used. The involved fields are numbered 1 to 11. Table 6.1 summarises briefly the characteristics of the farmers and the fields that were involved in the study.

The NPV, IRR, and opportunity cost of labour at break-even point were used as evaluation criteria for the CBA. The labour opportunity cost (OC) at break-even point is the point at which the wage for the investment costs of the terraces are "repaid" after 10 years (that is, when NPV = 0). It is expected that the multiple roots problem will not occur in the calculations of IRR, as in most cases the cash flows are only negative during the investment year, but become positive afterwards for all cases except case 7. The bench terraces were small and built by farmers who were not yet very experienced with terracing, thus the lifetime of the terraces were expected to be only 10 years. Furthermore, as most farmers were subsistence farmers, a long-term investment of more than 10 years was not expected. The discount rate is an important element in CBA, but it is difficult to determine the appropriate rate. There appears to be an informal consensus that the social rate of discount is usually around 5 to 10%, although the rationale behind these figures is often not clear (Bojö, 1992). Many empirical studies use private discount rates of 5 till 15%, with a maximum of 20% in some cases, for financial CBA of SWC practices (Clark, 1996; Enters, 1998). For this case study, a discount rate of 10% is applied, but in the sensitivity analysis, calculations are also carried out with discount rates of 5% and 20%.

For the fields of 2002 (fields *1* to *5*), an initial CBA was done with values on labour costs and crop production as given by the farmers, in order to determine the profitability of terraces according to the farmers' beliefs. A second CBA was done involving the data of all fields (*1 – 11*) using the crop production data as measured, and adjusting some extreme values given by the farmers, mainly concerning labour input. All CB-analyses are carried out for 0.1 hectare, since most farmers' fields are about this size.

Most terraces were quite small. Only the farmer of fields *5* and *7* has made considerable effort to construct terraces, followed by the owners of fields *2* and *9*. All farmers participated in MARENASS, only the farmers of fields *4* and *6*, and *8* joined the activities of PRONAMACHCS as well. All fields were near the farmer's house, and in most cases stones were available in the field for the construction of the terraces. The main reasons to construct the terraces were to prevent soil loss and improve cropping conditions on fields with many stones and steep slopes. All farmers used both family labour and *ayni* for the construction of the terraces. *Ayni* is a traditional system of reciprocal labour exchange that enables the farmers to have a huge amount of extra-household labour at their disposal in case needed. Most farmers derived cash income from off-farm activities. All farmers were male, except for an old widow (*11*); her daughter helped her with her agricultural activities.

Maize was the main crop cultivated on the terraces and the adjacent slopes. The grain production of maize multiplied with the average market prices was thus used to calculate the benefits. In 2002, other crops (beans, potato, oat) were grown on a few terraces as well together with maize. In these cases, the farmers' estimations of the yields of these crops were used, and added to the value of the maize yield. Though the measured yields are only a snapshot of the processes going on, it is assumed that the yields as measured will be an average of the yields as expected for the coming years, as the measured yields were regular according to the farmers. Yields are assumed to remain constant in the "with bench terraces" situation. In the "without" situation, it is assumed that yields slowly decline over time, as the farmers stated that the soil fertility in their sloping fields was declining, resulting in decreasing yields. A soil loss rate of 10 till 70 Mg ha^{-1} y^{-1} was assumed (see section 3.1.3) depending on the slope. The relation between soil loss and yield decline was simplified by assuming a linear relation between yield decline and loss of soil depth. Allowing a minimum soil depth of 0.3 m, the following equation is obtained:

$$YD = \frac{0.1 * SL}{(D - 0.3) * SD} * 100\% \qquad [6.3]$$

where: YD = annual yield decline (%)
SL = soil loss (Mg ha^{-1} y^{-1})
D = soil depth (m)
SD = soil density (kg m^{-3})

The annual yield decline is calculated at a rate of 1 to 3%, depending on the local conditions. These rates are similar to other findings (Grohs, 1994; Flörchinger, 1998). In a few cases (*1*, *8* and *9*) terraces were constructed on a sloping field on which the owners were not cultivating before the installation of the terraces. Yield in the without situation was zero for these cases.

Table 6.1 *Characteristics of selected farmers and fields used for CBA*

Fields	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***
Terraces (m^2)	373	832	289	434	1570	126	1570	271	551	274	188
Field on slope (m^2)	800	640	209	690	500	68	1365	748	4125	1050	789
Natural slope (%)	12	50	45	15	35	35	35	45	10	45	5
Maize yield terraces (kg ha^{-1})	5553	8289	7418	5238	2464	2811	3130	3898	4476	5318	4214
Maize yield slope (kg ha^{-1})	–	491	12356	4050	923	1637	3814	–	–	4106	3848
Soil type	Loam	Clay loam	Clay loam	Clay loam	Clay loam	Clay loam	Clay loam	Loam	Loam	Clay loam	Clay loam
Soil depth terrace (m)	0.50	0.50	0.70	0.70	0.60	0.60	0.60	0.60	0.50	0.50	0.60
Soil depth slope (m)	0.60	0.45	0.50	0.90	0.50	0.50	0.50	0.45	0.70	0.45	0.70
SOM[1] terrace (%)	3.0	3.0	2.2	2.4	1.6	3.3	4.3	3.4	3.2	3.1	3.9
SOM[1] slope (%)	2.4	2.4	3.2	3.2	2.9	5.3	3.7	3.5	3.0	3.8	3.9
Soil loss[2] (Mg ha^{-1} yr^{-1})	40	70	70	40	55	55	55	70	40	70	25
Annual yield decline (%) on slope	1	3	3	1	2	2	2	3	1	3	1
Distance field to farmhouse (m)	500	100	50	0	0	50	0	0	50	500	0
Access to irrigation water in dry season	no	yes	no	yes	no	no	no	no	no	no	yes
Family size	5	4	4	3	5	3	5	2	3	4	2
Age head household	41	29	30	62	59	62	59	64	54	45	65
% of total household labour spent off-farm	30%	30%	70%	15%	30%	15%	30%	0%	15%	30%	0%
Reasons for construction of terraces	To recover land	Stones / steep slope	Stones / steep slope	Prevent soil loss	Stones / prevent soil loss	Prevent soil loss	Stones / prevent soil loss	To recover land	Program recomm.	Steep slope / stones	Program recomm.

[1] SOM = soil organic matter content
[2] The different categories of soil loss are estimated based on the slope of the field and literature.
Note: fields 4+6 and 5+7 are different fields from two farmers.

The total costs of the bench terraces are mainly determined by the labour costs required for the construction and maintenance. For the valuation of labour the standard market wage of S/. 10 per day[9] and an opportunity cost of labour S/. 5 per day were used. The opportunity cost of labour can be assumed to be much lower than the market wage, as off-farm employment is not available all year around. The terraces are normally constructed during periods with less agricultural activities. An extra cost of S/. 60 was added to the investment costs for each case, for the tools needed to construct the bench terraces.

The farmers received direct incentives from the programmes for the construction of the bench terraces. In case of PRONAMACHCS, they received tools for the terrace construction. MARENASS organized farmer competitions, and participating farmers had the chance to win S/. 150 in the first year after the construction of the terraces. All farmers participating with PRONAMACHCS got tools for free during the construction period, reducing slightly the investment costs. The value of the tools received, was estimated at S/. 60. The average establishment costs for the terraces was S/. 744 per 0.05 hectare – the average size of the terraces. The value of the programme incentives was thus much lower than the investment the farmers have to make. Still, one of the justifications to provide programme incentives to resource-poor farmers is that it helps them to overcome the high investment costs (see section 2.3 for further discussion). Therefore, the effect of incentives on the profitability of bench terraces was analysed as well. The IRR and opportunity cost of labour at break-even point were calculated in case farmers received programme incentives for the construction of the terraces, and in case they did not.

In order to test some of the assumptions, a sensitivity analysis is applied for the following factors: discount rate (5% and 20% against 10%), time horizon (5 and 15 years against 10 years), the assumed yield decline in the "without" case (0% and doubled decline of 2-6% against 1-3 %), and the cropping pattern (maize mono-cropping against diversified cropping pattern). The latter only applies to 2002, because in 2003 only maize was cultivated on the fields that were used for this CBA case study. In order to estimate the returns to the farmers only the opportunity costs of labour at break-even points were calculated in the sensitivity analysis instead of the NPVs.

6.3 The profitability of bench terraces

During the interviews, most farmers were enthusiastic about their terraces. They all stated that production had increased, the decline of soil fertility was stopped, and that most agricultural activities had become easier, as less labour was required for mainly weeding and harvesting. Table 6.2 shows the results of the CBA based on solely the farmers' estimations of labour inputs, production costs and yields on the terraced and the sloping fields. Except for *4*, the farmers' estimates about the costs and benefits of their terraces show that the terraces are quite profitable. According to the farmers estimations, the construction of terraces would result in an average opportunity cost of labour of S/. 12.6, which is quite attractive, as this is more than the market wage (S/. 10).

In Table 6.3 the farmers' estimations of the maize yield are replaced by the yield measurements. For the other crops cultivated, the farmers' yield estimations are used. Some farmers' estimations about labour input are adjusted, using the averaged values of the interviews and a survey that was carried

[9] The Peruvian currency is Nuevo Sol (S/.); the exchange rate in 2002 was: US$ 1 = S/. 3.50

out early 2002 (see Chapters 4 and 7). The CBA results are recalculated twice: in case programme incentives are given, and if only maize has been cultivated. Surprisingly, four out of five farmers believe their terraces to be more profitable (Table 6.2) than what we measured (Table 6.3) in 2002.

Table 6.2 *CBA using farmers' estimations (labour costs and yields), 2002*

Fields (field sizes are standardised to 0.1 ha)	***1***	***2***	***3***	***4***	***5***	***2002 (average 1-5)***
Establishment labour costs (mandays)	118	119	159	147	124	133
Value production terraced field (S/.)	803	422 [1]	1055	539	525	669
Value production sloping field (S/.)	–	156	526	367	364	353
Annual yield decline sloping field (%)	–	3	3	1	2	2
NPV (S/.) at 10% discount rate, labour cost of S/.10 per manday	1332	-134	520	-774	1343	339
IRR at labour cost of S/.10 per manday	34%	7%	17%	-5%	32%	16%
IRR at labour cost of S/.5 per manday	92%	28%	49%	8%	44%	37%
OC labour at break-even point at 10% discount rate (S/. per manday)	14.6	9.0	12.0	4.6	n.a. [3]	12.6
IRR, with programme incentives, labour cost of S/.10 per manday	37%	10%	19%	-4% [2]	35%	18%
OC labour at break-even point, with programme incentives (S/. per manday)	15.0	9.9	12.5	4.9 [2]	n.a. [3]	13.6

[1] For the oat production an average production of 900 kg ha^{-1} is used, based on the survey of 2002.
[2] This farmer participated with PRONAMACHCS and thus "only" received tools as programme incentives.
[3] No appropriate opportunity cost of labour can be calculated as the production costs are higher than the gains, resulting in negative profit, in the without case.

Table 6.3 *CBA using measured data and adjusted farmers' estimations, 2002*

Fields (field sizes are standardised to 0.1 ha)	***1***	***2***	***3***	***4*** [1]	***5***	***2002 (average 1-5)***
Establishment labour costs (mandays)	118	119	159	147	124	133
Value production terraced field (S/.)	598	386	807	916	479	618
Value production sloping field (S/.)	–	74	453	1334	285	537
Annual yield decline sloping field (%)	–	3	3	1	2	2
NPV (S/.) at 10% discount rate, labour cost of S/.10 per manday	187	75	-96	-1731	-869	-1108
IRR at labour cost of S/.10 per manday	14%	11%	9%	–	-11%	–
IRR at labour cost of S/.5 per manday	60%	35%	32%	–	15%	3%
OC labour at break-even point at 10% discount rate (S/. per manday)	10.6	10.5	9.5	0.8	5.6	3.8
IRR, with programme incentives, labour cost of S/.10 per manday	17%	14%	10%	– [2]	-9%	–
OC labour at break-even point, with programme incentives (S/. per manday)	11.0	11.4	10.1	1.1 [2]	6.2	4.5
IRR, only maize production, labour cost of S/.10 per manday	14%	60%	–	-1%	-1%	-5%
OC labour at break-even point, only maize production (S/. per manday)	10.6	>15 [3]	3.6	6.4	7.4	6.1

[1] In this case second crop during dry season is potato; the farmer cultivated the second crop only on the bench terraces.
[2] This farmer participated with PRONAMACHCS and thus received tools as programme incentives.
[3] No appropriate opportunity cost of labour can be calculated as the production costs are higher than the gains, resulting in negative profit, in the without case.

Replacing the estimated maize yield with the measured maize yield (Table 6.3) results in an average opportunity cost of labour of only S/. 3.6. The opportunity cost of labour raises to S/. 4.3 after inclusion of the programme incentives. In case of maize mono-cropping, terraces are slightly profitable with an opportunity cost of labour of S/. 6.4. The value of land is determined by its land use, and the profitability of terraces is thus determined by the crops that are cultivated, i.e. high-value crops (e.g. potato, maize) result in a higher profit than low-value crops (e.g. beans, oat, wheat, barley). The cropping pattern has a larger influence on the profitability of terraces than the provision of programme incentives.

In 2003, 6 other sites were evaluated (Table 6.4). Maize was sown on all sites. Only on field *7* beans were sown as well, but the yield was unknown. Therefore, only maize production is considered for all cases for the CBA analyses of 2003. Except for *8* and *9*, it seems that the terraces are not very efficient in financial terms. Considering only maize production for both years, the terraces analysed in 2003 are less profitable than those in 2002. This might be explained by the rainfall pattern. The farmers stated that in 2002 there was a dry spell during the rainy season affecting the maize on the slopes but less so on the terraces, whereas 2003 was a year with a regular and well-distributed rainfall pattern. Bench terraces have a waterconserving effect, and reduce the risk of crop failure due to drought, as happened in 2002.

Table 6.4 *CBA using measured data and adjusted farmers' estimations, 2003*

Fields (field sizes are standardised to 0.1 ha)	***6***	***7***	***8***	***9***	***10***	***11***	***2003*** *(average 6-11)*
Establishment labour costs (mandays)	159	124	203	131	155	133	154
Value production terraced field (S/.)	336	352	462	512	612	515	465
Value production sloping field (S/.)	220	414	–	–	463	449	387
Annual yield decline sloping field (%)	2	2	–	–	3	1	2
NPV (S/.) at 10% discount rate, labour cost of S/.10 per manday	**-1331**	**-2344**	**-707**	**603**	**-906**	**-1122**	**-1225**
IRR at labour cost of S/.10 per manday	–	–	**0%**	**20%**	**-6%**	–	–
IRR at labour cost of S/.5 per manday	**-5%**	–	**27%**	**57%**	**11%**	**-4%**	**1%**
OC labour at break-even point at 10% discount rate (S/. per manday)	**2.4**	**-1.2**	**7.6**	**12.9**	**5.1**	**2.6**	**3.5**
IRR, with programme incentives, labour cost of S/.10 per manday	–	–	2%	23%	-4%	–	–
OC labour at break-even point, with programme incentives (S/. per manday)	3.1	-0.6	8.0	13.5	5.8	3.4	4.2

In Figure 6.1 the results of the sensitivity analysis for the opportunity costs of labour at break-even points under different assumptions are depicted. Though different assumptions change the absolute values of CBA results, it does not change the conclusions under which circumstances terraces are profitable or not. The figure shows that the break-even opportunity costs of labour for the construction of terraces in most cases and circumstances are between S/. 0 and S/. 10 per manday.

For fields *1, 8* and *9*, in the without cases no crops were cultivated. The farmers decided to install the terraces on small pieces of land that were not under cultivation. This explains the high profitability of these terraces, because it enabled the farmers to cultivate on a piece of land they otherwise would not use. Note that *1* and *9* installed their terraces on fields with a gentle slope. Erosion might not have been a real problem here.

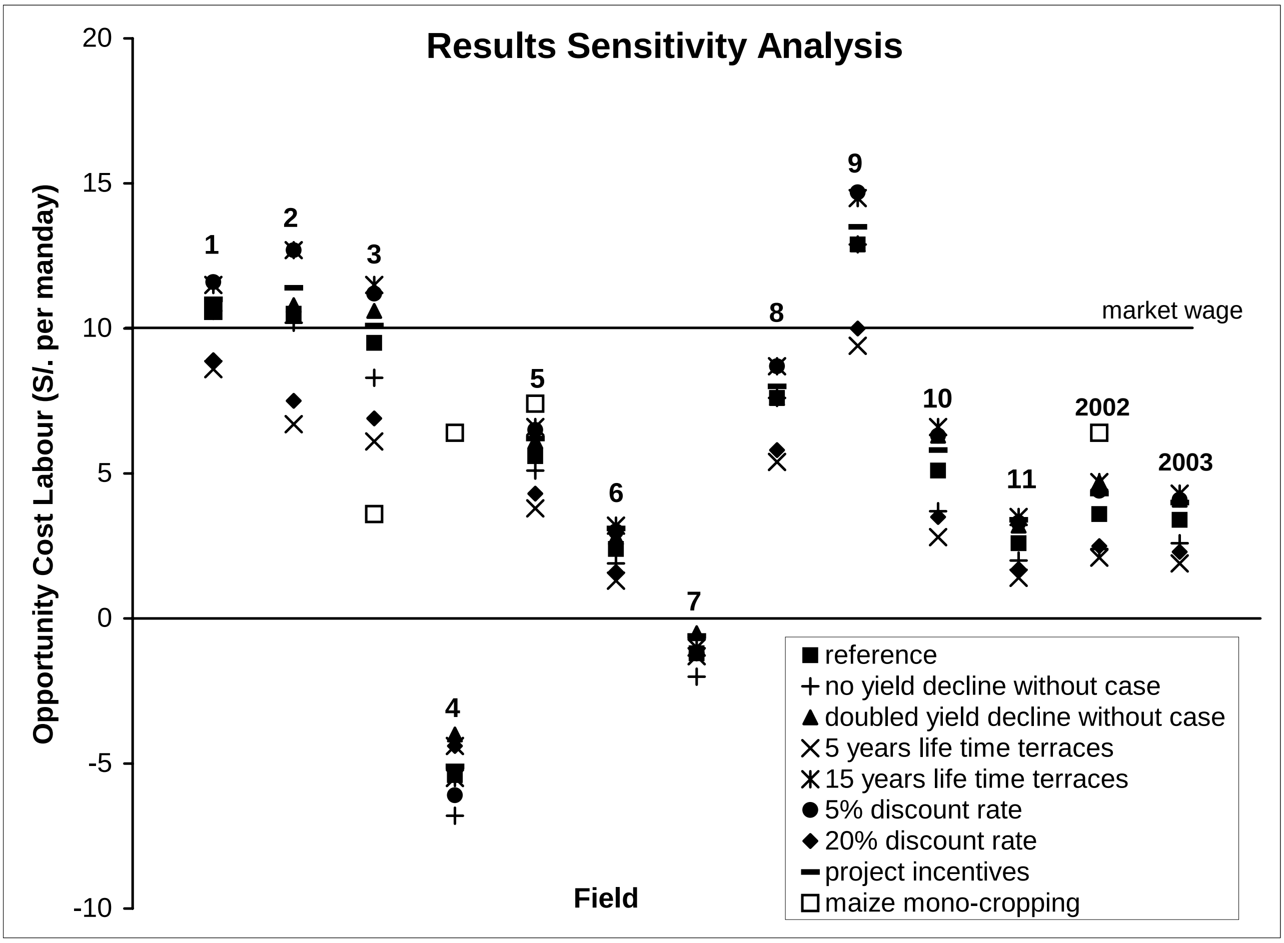


Figure 6.1 Sensitivity analysis of the financial CBA results on bench terraces

The owner of field *2* is quite successful with his terraces, which are built on a steep and degraded field. This farmer is the only one out of five who underestimated the profitability of his terraces, as he under- and overestimated the maize yields on the terraces and the sloping field respectively. This farmer also cultivated food crops like beans and oat on his terraces, which he could not cultivate on his sloping field. A quarter of his terraces he left fallow, but if he had fully used his terraces, the profitability would have been much higher. In case of maize mono-cropping, the opportunity cost of labour would even become S/. 32. Furthermore, it is possible to produce two crops a year, as irrigation water is available during the dry season. However, there is some risk of frost during this period. Though terraces enable the farmer to improve and increase his agricultural production considerably, he is only interested in meeting the consumption needs of his family and not in selling surplus at the market. This explains the “modest” profitability of his terraces, as the farmer sees no need to fully exploit his terraces.

The farmer of field *3* estimated the labour inputs and investment costs high. He successfully cultivates different crops (maize, beans and potatoes) on his terraces, which is not possible on the sloping field. If he had only cultivated maize, the profitability of the terraces would have been disputable. However, as the farmer overestimated the maize yield, this might be the same case for the potato and bean production. Whether profitable or not, this farmer seemed to be less interested in his terraces, as he has full-time off-farm employment resulting in a high personal opportunity cost of labour. Also, he possesses fertile fields as well where he can produce sufficient food to meet the consumption needs of his household.

The disappointing results of *4*, *6* and *10* can be explained by the fact that the soil fertility of the sloping fields is higher than the soil fertility of the terraces. As the terraces are installed on a more degraded part of the fields, a simple comparison in production is probably not the right method. Furthermore, *4* and *6* did not suffer water shortage, so the extra benefit of water conservation did not have any positive effect on the production on the terraces. Unfortunately, we do not have data about crop production "before" the implementation of the terraces. That might have given us more accurate results. If we consider low opportunity costs for labour, the terraces *10* become profitable. The opportunity cost of labour of this farmer is probably low, as his main activity is agriculture. Only in case he needs cash money and if temporarily employment off-farm is available, he will use his labour for off-farm activities. Fields *4* and *6* are owned by the same farmer. According to the farmer, the terraces *4* are fairly profitable. But the contrary appears from our measurements.

Fields *5* and *7* belong to the same farmer. We measured the yields on the same location in both years, though the maize was sown on a different part of the sloping field in 2003 (*7*) than in 2002 (*5*). The farmer estimated the output on the sloping field *5* to be very low. This implies that the value of the production (the gain) is lower than the production costs, resulting in a negative profit on his sloping field. As in CBA the costs in "without" case are considered as benefits in the "with" case, we could not estimate the opportunity costs for the break-even point (table 7). Contrary to *5*, for *7* the average maize production was lower on the terraces than on the sloping field, resulting in a non-profitable outcome. An explanation might be that for *7*, the cropping density on the terraces (about 50,000 plants per ha) was much lower than on the sloping field (about 70,000 plants per ha) in contrast to *5* when it was the other way around. But also the cropping pattern determines the profitability of the terraces. In case of *5* also potatoes were cultivated but not in case of *7*. Nevertheless, the farmer is aware of the soil degradation on his fields, and continues constructing terraces. He also stated that terracing is an efficient way to get rid of the many stones in his sloping field. Better financial results might be obtained if improved cropping practices like fertiliser input and sowing techniques are applied, and more high-value crops like potato are cultivated.

The disappointing results of *11* can be explained by the fact that these terraces are installed on a place where it is not necessary, as the slope is gentle (only 5%) and soil fertility is high. The slightly higher maize production on the terraces compared to the sloping field is probably due to different maize varieties and not the practice of terracing itself. The farmer stated that she constructed the terraces because she participated in the farmer competitions of MARENASS, and not necessarily to improve her field or production.

If it is assumed that terraces are financially effective whenever the opportunity cost of labour of terracing is positive, there are only two cases in which this requirement is not fulfilled. In order to know whether the terraces are financially attractive to a farmer, one has to compare the opportunity cost of labour of terracing with the personal opportunity cost of labour of the farmer. Though the market wage rate is S/. 10 per manday, a lower personal opportunity cost of labour for most farmers can be assumed. Case *3* is an exception, because this farmer has a full-time off-farm employment, and his personal opportunity cost of labour is estimated at the market wage rate. Though his terraces are quite profitable compared to other cases, they are not very attractive to this farmer. The terraces *4*, *5*, *6, 7*, *8* and *11* are less profitable, but apparently these farmers estimate their personal opportunity cost of labour at very low rates. As these farmers are old and hardly undertake any off-farm activities, low personal opportunity costs of labour for these farmers are indeed expected. Awareness of soil erosion problems in their sloping fields also was an extra stimulus for the owners of fields *4*, *5*, *6,* and *7* to install terraces.

6.4 Conclusions

Due to the improved growing conditions caused by terracing, crops can be sown more densely and high-value crops like vegetables, potatoes or improved maize varieties can be cultivated. This results in higher productivity, and thus higher profitability of the terraces. The steeper and more degraded the field, the more pronounced the positive effect of terracing on productivity. However, when farmers (like in case *7*) do not take advantage of these improved conditions, terraces become unprofitable in any case. Construction of terraces is thus not enough, but has to be combined with the extension and introduction of improved agricultural practices like sowing techniques, fertilisation and crop rotation. Terraces also enable cropping activities on fields that were left out of cultivation because of slope or stones. Terracing also reduces the risk of crop failure during dry spells in the rainy season, due to the water conserving effect.

The farmers believed their terraces to be more profitable than what we measured. This was surprising, as it is often said that farmers are reluctant to implement terraces because of the uncertain profitability. Whether terracing is profitable depends on local agro-ecological conditions and is thus site-specific. Whether terracing is financially attractive to a farmer depends on the socio-economic circumstances, and is thus very personal. For one farmer terracing can be a financially attractive investment, whereas for his neighbour it is not. When a low personal opportunity costs for labour can be assumed instead of the market wage rate, terracing becomes more attractive. As most farmers are employed only occasionally, and off-farm labour is not available all the year round, a personal opportunity cost of labour below the market wage rate can be justified. In our research it was the case for all farmers, except for one. In case farmers receive programme incentives when they install terraces, the effect on the opportunity costs of labour is slight. Though it is often believed that farmers only construct terraces in order to receive the programme incentives, this does not seem logic when considering all costs and benefits. Though programme incentives might convince farmers to install terraces, it does not make the terraces considerably more attractive in financial terms.

Using the break-even opportunity cost of labour of terracing as an indicator for the profitability of terracing is a useful tool to understand farmers' rationale. Farmers who depend on steep and degraded fields for their food production and income and who have a low personal opportunity cost of labour, are more keen on terracing, as this investment improves their livelihood. Farmers with access to fertile fields for agricultural production, and who also rely on off-farm income, will be less interested in terracing, as it is less financially attractive to them.

Profitability of terraces is thus site- and household-specific. It depends on the field characteristics, farm management as well as the opportunity costs of the farm household labour. Similar conclusions were drawn by Lutz et al. (1994b) and Valdivia (2002). The profitability of SWC practices depends on the specific agro-ecological conditions faced, technologies used, on prices of inputs used an of output produced, and markets (Lutz et al., 1994b; Wiener et al., 2003). Terraces are most likely to be profitable on steep slopes, and farmers will invest in terraces with the highest private benefits (Valdivia, 2002).

Chapter 7

Farmers' adoption behaviour of soil and water conservation practices

A revised version of this chapter is in preparation as:
H. Posthumus, C. Gardebroek and R. Ruben (*in preparation*). Farmers' adoption behaviour of soil and water conservation practices in the Peruvian Andes.

7 Farmers' adoption behaviour of soil and water conservation practices

There is a wide-spread concern about the threat of soil erosion, decreasing agricultural production, and a possible decline in food security, in many rural areas in developing countries (LDCs). Therefore, initiatives have been taken to prevent soil erosion and to promote sustainable agriculture by introducing soil and water conservation (SWC). Programmes on resource conservation and sustainable agriculture were initiated to induce farmers to manage their land in a sustainable way. The justification of these programmes is that without external intervention farmers will not invest in SWC. Even if SWC practices are profitable, this is not a guarantee for adoption, as other factors may prevent a farm household from adopting a new technology (Lutz et al., 1994a). The profitability of SWC practices is sensitive to key bio-physical and economic variables, such as initial soil conditions, discount rates and the effects of SWC on long term productivity (Antle et al., 2004). Furthermore, farmers face constraints like limited assets and market failures (lack of information, no access to credit) that impede adoption of SWC technologies. Programmes promoting SWC often rely on incentives to attract farmers and motivate them to implement SWC practices. However, the criticism of these programmes is that the SWC practices they promote are often not maintained. As soon as the support ends, farmers abandon the SWC practices because they were not really interested in these practices, as these interfere with current agricultural practices and lowers short-term agricultural output and profit (Winters et al., 2004).

The Peruvian government started SWC programmes in the 1980s through the establishment of the governmental programme PRONAMACHCS. Also many local NGOs started SWC activities at this time. In 1998, the Peruvian government launched a pilot-programme, MARENASS, in order to try a participatory approach instead of the top-down approach of PRONAMACHCS. The importance of these programmes and farmers' adoption behaviour are analysed in this chapter in order to find the most important factors determining adoption of SWC practices in the two watersheds Pacucha and Piuray-Ccorimarca, Peru. Since the programmes working in the two watersheds as well as the physical and social conditions are different (see also Chapter 4), it is expected that the adoption process in Pacucha differs from the one in Piuray-Ccorimarca.

7.1 Materials and methods

7.1.1 Conceptual model of adoption process

Sociologists consider the adoption process of new technologies as a multi-stage learning and decision process, during which a farmer or producer passes from first hearing about an innovation to final adoption (Rogers, 1962). The adopter-perception simplifies this process into a conceptual model consisting of three stages (section 2.2). However, this paradigm considers farmers' perception as the starting point before the adoption decision (Ervin and Ervin, 1982; Lynne et al., 1988; Sinden and King, 1990). Though perception definitely influences adoption, perception cannot be used as a starting point in an *ex-post* evaluation of adoption behaviour, as perception is not static but dynamic and changing during the adoption process. Often farmers' perception is "measured" after the adoption decision is made. It is quite likely that the perception after adoption is different from before the adoption. This makes the use of farmers' perception as starting point questionable.

Leaving aside a few exceptions, most farmers in the research areas who implement SWC practices are involved in at least one SWC-oriented programme. Therefore, it is assumed in this case study that programme involvement is the starting point of the adoption process (see also: Cramb et al., 1999; Jagger and Pender, 2003). SWC-oriented programmes are important institutions for the dissemination of information about new technologies, and provide various incentives in order to stimulate farm households to adopt SWC practices. Based on the adopter-perception paradigm, the following conceptual model can be drawn (Figure 7.1).

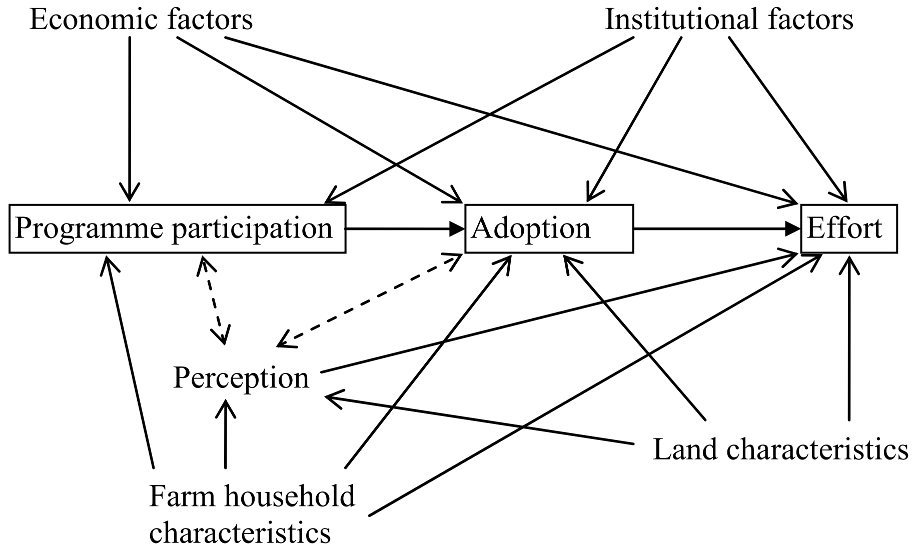


Figure 7.1 Conceptual model of the adoption process of SWC practices (based on Ervin & Ervin, 1982)

In this conceptual model, the adoption process is split up in several stages. However, a three-step econometric model is complicated, as multiple treatment effects and sample selectivity problems arise. Therefore, in this chapter only the first two steps will be considered initially in order to estimate the impact of programmes on adoption. It is assumed that a farm household first makes a decision whether to participate in an SWC-oriented programme or not. The second stage is to decide whether to implement SWC practices promoted by the programme (see Figure 7.2).

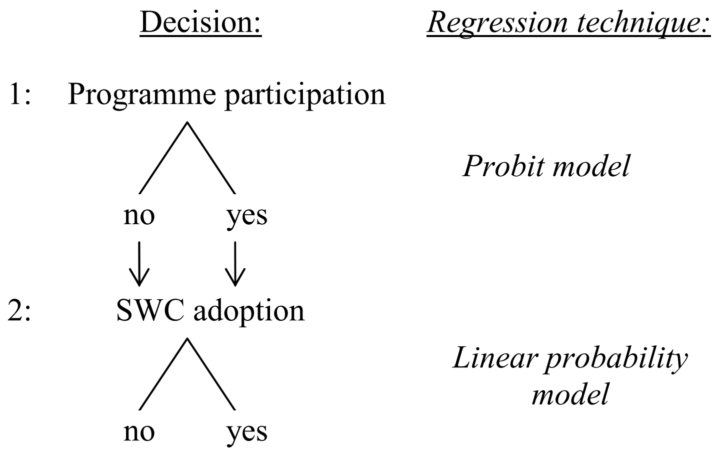


Figure 7.2 Decision tree for estimating adoption of SWC practices

Programme participation means that a farm household has contact at least once a year with field staff of the programme, and is represented by a binary variable. When a new programme is to start, the interventions are announced during the general meeting (*asamblea general*) of the community. In principal, all farm households have equal access to the programmes. Though programmes approach communities through the community councils, the decision to participate in a programme is made at household level. Farm households participate in a programme because they expect that their utility as participants will be higher than the level of utility they would obtain as non-participants (Edmonds, 1999). Adoption is defined as the decision of the farm household to implement at least one SWC practice on its own land. Because of the limitations of this study the adoption decision is only evaluated at one moment in time. The econometric models will be estimated with the software STATA 8.

7.1.2 Econometric methods for analysis of adoption behaviour

Choices are often dichotomous: it equals 1 if the i^{th} individual chooses for a certain action, and 0 otherwise. Probit and logit models are the most popular statistical models developed to analyse dichotomous response variables (Asfaw and Admassie, 2004). These models assume an underlying response variable y_i^* defined by the regression relationship:

$$y_i^* = \beta x_i + \varepsilon_i \qquad [7.1]$$

where x_i is a set of independent variables of individual i, β is the set of coefficients to be estimated and ε_i is the error term. In practice, y_i^* is unobservable. What one observes is a binary variable y_i defined by

$$y_i = 1 \quad \text{if } y_i^* > 0 \qquad [7.2]$$
$$y_i = 0 \quad \text{otherwise}$$

Then one gets:

$$\text{Prob}\left(y_i = 1\right) = \text{Prob}\,\varepsilon_i > -\beta x_i = 1 - \Phi\left(-\beta x_i\right) = \Phi\left(\beta x_i\right) \qquad [7.3]$$

where Φ is the cumulative distribution function for ε (Maddala, 1983).
If Φ of equation [7.3] is chosen to be standard normal, then the probit model is given by (Johnston and DiNardo, 1997):

$$\text{Prob}\left(y_i = 1\right) = \Phi\left(\beta x_i\right) = \int_{-\infty}^{\beta x_i} \frac{1}{\sqrt{2\pi}} e^{\left(-\frac{1}{2}t^2\right)} dt\,, \qquad [7.4]$$

where t is a standardised normal variable with a mean of zero and a variance of one. The normal density function φ is given by (Maddala, 1983):

$$\phi(t) = \frac{1}{\sqrt{2\pi}} e^{\left(-\frac{1}{2}t^2\right)} \qquad [7.5]$$

Decision on programme participation and adoption

It is assumed that a farm household participates in a programme when the expected utility of participation $E(U^P)$ is higher than the expected utility of no participation $E(U^0)$:

$$P^* \equiv E\left(U^P\right) - E\left(U^0\right) > 0 \qquad [7.6]$$

However, P^* is not observable, but P is equal to one if the farm household participates in a programme, which is observable:

$$P = \begin{cases} 1 & \text{if } P^* > 0, Z\gamma > -\nu \\ 0 & \text{if } P^* \leq 0, Z\gamma \leq -\nu \end{cases} \quad [7.7]$$

Equations [7.6] and [7.7] account for the adoption decision as well. Though A^* is not observable, A is observable and equals one when a farm household adopts SWC practices:

$$A = \begin{cases} 1 & \text{if } A^* > 0, X\beta + P\alpha > -\varepsilon \\ 0 & \text{if } A^* \leq 0, X\beta + P\alpha \leq -\varepsilon \end{cases} \quad [7.8]$$

Though most farm households who adopt SWC practices also participate in an SWC-oriented programme, the latter is not conditional for the adoption decision, as non-participants can also decide to adopt SWC practices. The econometric model thus has to deal with a treatment effect, as programme participation can be considered as a treatment (Greene, 1997).

Estimating programme impact on adoption behaviour

The essential problem of evaluating any impact of a programme is that the outcomes for participants if they had not participated, cannot be observed (Ravallion, 2001). Therefore, a problem of missing-data on the counter-factual arises (Blundell and Costa-Dias, 2000; Godtland et al., 2003). Randomised experiments would solve this problem by generating an experimental control group of people who would have participated in a programme but who were randomly denied access to the programme (Greene, 1997). However, denying farm households access to programme randomly is unethical and politically difficult (Baker, 2000). Therefore, non-participants are often used as a comparison group to evaluate programme impact (Heckman et al., 1998). But these observations in the comparison group are not randomly distributed. The farm households can self-select into the group of programme participants (or not), causing a self-selection bias (Edmonds, 1999). This implies that unobserved variables influencing programme participation, might influence the adoption decision as well (Baker, 2000), resulting in a "selection on unobservables" (Godtland et al., 2003). If this is the case, the estimation of the coefficient of programme participation – the programme impact on adoption – will be biased (Blomquist, 2003). In other words, it might be that differences between adopters and non-adopters is not due to the programme impact, but due to this self-selection process.

The adoption decision [7.8] can thus be written as:

$$A_i^* = X_i\beta + P_i\alpha + \varepsilon_i \quad [7.9]$$

where X is a set of exogenous variables explaining A, P is a dummy variable such that $P_i = 1$ if individual i participates in a programme and $P_i = 0$ otherwise, and ε_i is the error term of mean zero and uncorrelated with X. Remind that the participation decision P is given by:

$$P_i^* = Z_i\gamma_i + \nu_i \quad [7.10]$$

The error terms ε_i and ν_i contain measurement errors and unobserved variables explaining A and P respectively. If the same unobserved variables are jointly influencing A and P, ε_i and ν_i might be correlated causing a selection bias, as explained above. For cross-section data, two standard approaches are often used in evaluation studies to correct for the selection bias: the instrumental variable approach and the Heckman selection estimator (Blundell and Costa-Dias, 2000). In this chapter the Heckman selection estimator is used.

The Heckman selection estimator is based on the work of Heckman (1979), and is more robust than the instrumental variable estimator, but also more demanding on assumptions about the model (Blundell and Costa-Dias, 2000). Remind that the source of the bias is the correlation between the two error terms ε_i and υ_i. A natural way to solve the problem when one has an instrumental variable is to add the residuals from the participation equation to the adoption equation but keeping actual participation in the adoption regression (Baker, 2000). In other words, in the first stage the probability of participating in the programme and the error term υ_i are estimated as before, and in the second stage the υ_i is used to statistically adjust the disturbance term ε_i in the adoption regression so that the programme impact estimate will be unbiased, as the true programme impact is separated from the selection process (Blundell and Costa-Dias, 2000; Blomquist, 2003). The error terms are assumed to be jointly distributed, i.e. to be bivariate, normally distributed with expected means of zero, standard deviations σ_ε and σ_υ, and covariance $\rho_{\varepsilon\upsilon}$. Adopting the standardisation σ_υ=1, the conditional outcome expectation (the adoption decision) is written as (Blundell and Costa-Dias, 2000):

$$E\left(A_i^* \middle| P_i = 1\right) = \beta_i X_i + \alpha + \rho \frac{\phi(Z_i\hat{\gamma})}{\Phi(Z_i\hat{\gamma})} \qquad [7.11]$$

$$E\left(A_i^* \middle| P_i = 0\right) = \beta_i X_i - \rho \frac{\phi(Z_i\hat{\gamma})}{\Phi(Z_i\hat{\gamma})} \qquad [7.12]$$

If the programme impact differs across agents (i.e. heterogeneous treatment effects), the adoption equation becomes (Blundell and Costa-Dias, 2000):

$$A_i^* = \beta_i X_i + P_i\left[\alpha_T + \rho_{(\varepsilon,\upsilon)} \frac{\phi(Z_i\hat{\gamma})}{\Phi(Z_i\hat{\gamma})}\right] + (1 - P_i)\rho_{(\varepsilon,\upsilon)} \frac{-\phi(Z_i\hat{\gamma})}{1 - \Phi(Z_i\hat{\gamma})} + \mu_i \qquad [7.13]$$

Note that α_T represents the programme impact on the programme participants only. This correction term is also called the Inverse Mill's Ratio (IMR). The IMR is equal to ϕ/Φ when P_i = 1 and is equal to $-\phi/(1-\Phi)$ when P_i = 0.

The standard procedure is to calculate the IMRs with the results of a probit model and then add them to an OLS equation. The adoption equation is a choice model though, and would normally be estimated with a probit model. However, the probit model assumes a homoskedastic error term (variance of error term is assumed to be equal to one), whereas the inclusion of IMRs causes heteroskedastic error terms. Therefore, the linear probability model is used instead of the probit model in this chapter. Though heteroskedasticity results in a loss of efficiency, the least squares estimates remain consistent and unbiased. The error terms are inconsistent though, which can cause problems when testing coefficients for their significance. Correction for heteroskedasticity through weighted least squares is not desirable as it is not efficient for finite samples and it is also sensitive to errors of specification (Pindyck and Rubinfeld, 1998). Instead, robust standard errors are calculated to obtain consistent estimates of the standard errors. The linear probability model has serious limitations for prediction, but it should be appropriate for the purpose of this chapter: explaining past adoption behaviour. The linear probability model might therefore be the most appropriate model for the construction of an adoption equation including IMRs. The F-test is used to test the zero hypothesis that the IMRs equal zero. If this hypothesis is accepted, the IMRs are omitted, and the adoption equation is estimated with probit models without the IMRs.

In the example above only one treatment or programme was taken into consideration. However, taking the example of Pacucha[10] two programmes promote SWC: PRONAMACHCS and MARENASS. Farm households can thus choose between two 'treatments'. If these choices for participation in PRONAMACHCS or MARENASS are independently made, IMRs for both programmes can be inserted into the adoption equation as the covariance of the two error terms (ν^P and ν^M) of the two equations is equal to zero, i.e., $\rho(\nu^P,\nu^M)=0$ (Maddala, 1983: p282). If the decisions whether to participate in PRONAMACHCS or MARENASS are not independent, only programme participation in general will be considered for simplicity, without distinguishing the two programmes. Whether the two decisions on programme participation are independently made, can be tested with a bivariate probit.

7.1.3 Sampling and data collection

In January and February 2002 a survey was carried out among 180 farm households in Pacucha and 192 farm households in Piuray-Ccorimarca. A stratified sampling procedure was applied in order to ensure that sub-samples of programme participants would be sufficiently large to carry out statistical analyses. Within each strata farm households were selected randomly. Three strata were defined in Pacucha: farm households not participating in any agriculture-oriented programme; farm households participating in MARENASS; farm households participating in PRONAMACHCS. In Piuray-Ccorimarca the following three strata were defined: farm households not participating in any agriculture-oriented programme; farm households participating in Arariwa; farm households participating in PRONAMACHCS. During the period of data collection it appeared that these three strata were difficult to find. Almost all farm households encountered were PRONAMACHCS participants, of whom a large part was participating in Arariwa as well. It might be that farm households who do not participate in any agriculture-oriented programme are not much interested in agriculture either, as they work off-farm, and were therefore not found at home by the interviewers.

After testing the survey, local students with knowledge of agriculture and of the local language *Quechua* were attracted in order to carry out the survey. The survey forms were checked on a daily basis during the data collection period, in order to correct any mistakes or vagueness made by the interviewer. In the survey, cross-sectional data was collected on farm household characteristics, the farming system, characteristics of farmland, agricultural production, programme participation, use of SWC practices, and the perception and opinion of the farm household. A few observations are left out of the analysis because of extreme values and unreliable or incomplete data.

7.1.4 Variables used in the adoption model

Different dependent variables are used for the separate stages. Also, the vector of independent variables explaining the successive decisions is changing, as it is assumed that different factors play a role for each decision. The dependent variables and their descriptives are presented in Table 7.1.

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[10] The same applies for Piuray-Ccorimarca: the programmes PRONAMACHCS and Arariwa promote SWC.

The independent variables are described in Table 7.2. Some independent variables are explained further in the text below:

Education: the education level of the head of farm household is ranked as follows: *Education* = 1 if no education; = 2 if primary school unfinished; = 3 if primary school finished; = 4 if secondary school unfinished; = 5 if secondary school finished; = 6 if higher education; = 7 if professional training.

Social standing: the head of farm household is considered to be actively involved in social life of community, if he is for example member of the community council or a committee.

Risk taker: the head of household was asked to give his preference between two different deals: a risky deal with a chance of high profit or loss, or a deal with moderate profit for sure. Expected profit of the two deals was the same. *Risk taker* = 1 in case the head of household choose the risky deal; 0 otherwise.

Long term: the head of household was asked to give his preference between two deals: more money on long-term, or less money on short-term. Again, the expected profit of the two deals was considered the same. *Long term* = 1 in case the head of household choose for the long-term deal; 0 otherwise.

Table 7.1 *Description of dependent variables used in adoption behaviour analysis*

Dependent variables		**Pacucha (N=176)**		**Piuray-Ccorimarca (N=188)**		
Variable	**Description**	**Mean**	***St.dev.***	**Mean**	***St.dev.***	
Programme participation						
Programme	= 1 if farm household is involved in a programme, 0 if not	0.693	*0.462*	0.931	*0.254*	***
MARENASS	= 1 if farm household is involved in MARENASS activities, 0 if not	0.568	*0.497*	*NA*	*NA*	
PRONAMACHCS	= 1 if farm household is involved in PRONAMACHCS activities, 0 if not	0.341	*0.475*	0.910	*0.288*	***
Arariwa	= 1 if farm household is involved in Arariwa activities, 0 if not	*NA*	*NA*	0.729	*0.446*	
Adoption decision						
SWC	= 1 if farm household has implemented any SWC practices, 0 if not	0.591	*0.493*	0.596	*0.492*	
Bench terrace	= 1 if farm household has implemented bench terraces, 0 if not	0.545	*0.499*	0.149	*0.357*	***
Slow-forming terrace	= 1 if farm household has implemented slow-forming terraces, 0 if not	0.142	*0.350*	0.335	*0.473*	***
Infiltration ditch	= 1 if farm household has implemented infiltration ditches, 0 if not	0.159	*0.367*	0.229	*0.421*	*

Means of both watershed are significant different at (*) 0.1 level, (**) 0.05 level, (***) 0.01 level

Table 7.2 *Description of independent variables used in adoption behaviour analysis*

Independent variables		**Pacucha (N=176)**		**Piuray-Ccorimarca (N=188)**		
Variable	**Description**	**Mean**	***St.dev.***	**Mean**	***St.dev.***	
Farm household characteristics						
Family size	Total amount of farm household members	5.108	*1.987*	4.745	*1.889*	*
Gender	= 1 if head of household is male, 0 if female	0.835	*0.372*	0.957	*0.202*	***
Age	Age of head of household	39.8	*13.0*	40.0	*12.6*	
Education	Ranking of education level of head of household	2.659	*1.259*	3.239	*1.329*	***
Dependency ratio	Number of household members younger than 16, divided by total number of household members	0.459	*0.223*	0.454	*0.217*	
Farm household assets						
Farm area	Total amount of hectares farmland owned by farm household	1.068	*1.409*	0.728	*1.166*	*
Livestock	Monetary value (S/.) of livestock owned by farm household	2523	*1901*	2417	*1585*	
Farm household behaviour						
Social standing	= 1 if head of household is actively involved in social life of community, 0 if not	0.324	*0.469*	0.436	*0.497*	**
Risk taker	= 1 if head of household is risk taker, 0 otherwise	0.489	*0.501*	0.596	*0.492*	**
Long term	= 1 if head of household chooses for long-term case, 0 otherwise	0.494	*0.501*	0.638	*0.482*	***
Market	Ratio of total agricultural production of farm household that is sold on the market	0.136	*0.210*	0.315	*0.231*	***
Off-farm / farm income	Amount of off-farm income divided by total value of farm production: crop and livestock	0.952	*0.190*	1.439	*1.956*	***
Presence	Number of months that head of household is present on farm during the last year	11.73	*1.098*	11.70	*1.064*	
Farm household motivation						
Incentives	= 1 if household adopted SWC because of programme incentives, 0 otherwise	0.040	*0.196*	0.154	*0.362*	***
Programme	= 1 if household adopted SWC because of it was recommended by programme, 0 otherwise	0.540	*0.500*	0.383	*0.487*	***
Agricultural production	= 1 if household adopted SWC because of increase agricultural production, 0 otherwise	0.080	*0.271*	0.144	*0.352*	*
Conservation	= 1 if household adopted SWC because of conservation purposes, 0 otherwise	0.034	*0.182*	0.059	*0.235*	
Farmland characteristics						
Valley	Ratio of total farmland located in valley	0.361	*0.357*	0.573	*0.376*	***
Rainfed	Ratio of total farm without access to irrigation	0.422	*0.348*	0.395	*0.400*	
Flat slope	Ratio of total farm without slopes, i.e. flat	0.352	*0.382*	0.559	*0.395*	***
Gentle slope	Ratio of total farm with gentle slopes	0.446	*0.386*	0.355	*0.367*	**
Steep slope	Ratio of total farm with steep slopes	0.201	*0.333*	0.085	*0.205*	***
Distance	Average distance in km from house till fields	1.355	*1.522*	0.854	*0.926*	***
No stones	Ratio of total farm without stones, used as an indication of soil degradation	0.374	*0.361*	0.697	*0.352*	***

Means of both watershed are significant different at (*) 0.1 level, (**) 0.05 level, (***) 0.01 level

7.2 Empirical results on adoption behaviour in Pacucha

7.2.1 Comparing programme participants in Pacucha

Comparing the characteristics of different programme participants gives more understanding of which farm households are involved in what type of programmes. Four sub-samples could be distinguished in Pacucha: those farm households who do not participate in any programme, farm households participating in PRONAMACHCS, farm households participating in MARENASS, and farm households participating in both programmes. Table 7.3 gives the average values of variables that differed significantly per sub-sample.

Table 7.3 *Comparison of sub-samples of programme participation in Pacucha*

Variable [A]	Significant difference Prob>F	No programme N = 54	Sub-sample PRONAM. N = 22	MAREN. N = 62	Both N = 38	*All N=176*
Farm household characteristics						
Gender head of household	0.07	0.76	0.95	0.81	0.92	*0.84*
Social standing head of household	0.00	0.11	0.45	0.39	0.45	*0.32*
Risk taker	0.06	0.56	0.64	0.48	0.32	*0.49*
Farm household assets						
Value agricultural production (S/.)	0.00	662	1872	1348	1492	*1234*
Agricultural production sold (ratio)	0.03	0.07	0.13	0.18	0.15	*0.14*
Total farm area (ha)	0.00	0.57	1.35	1.00	1.72	*1.07*
Total farm labour (mandays)	0.00	32.7	57.9	61.9	77.1	*55.7*
Ratio off-farm / farm income	0.00	1.74	0.48	0.48	0.88	*0.95*
Value livestock (S/.)	0.00	1757	3165	2934	2568	*2523*
SWC implementation						
SWC practice	0.00	0.07	0.55	0.89	0.87	*0.59*
Slow forming terrace	0.00	0.00	0.09	0.16	0.34	*0.14*
Bench terrace	0.00	0.04	0.50	0.84	0.82	*0.55*
Infiltration ditch	0.02	0.04	0.14	0.23	0.24	*0.16*
Labour invested SWC (mandays)	0.00	1	19	38	66	*30*
Farmland with SWC (ha)	0.00	0.02	0.37	0.48	0.81	*0.40*
Motivation						
SWC: programme recommended	0.00	0.00	0.59	0.81	0.84	*0.54*
SWC: because of incentives	0.03	0.00	0.00	0.10	0.03	*0.04*
No SWC: lack of labour / money	0.00	0.28	0.23	0.58	0.42	*0.41*
No SWC: lack of knowledge	0.00	0.22	0.05	0.02	0.03	*0.09*

[A] *Variables without units are dummy variables. The average values presented in the table are ratios.*

Looking at the household characteristics it appears that farm households involved in programmes are more actively involved in the community (social standing). PRONAMACHCS participants are mainly male headed households and risk takers, whereas MARENASS participants are more risk-averse. Farm households participating in both programmes are most reluctant to risk. Participating in a programme is apparently not seen as a risk, but rather as a mean to diversify risk. Note that a quarter of the non-participating farm households was female-headed. These female-headed households have less labour available[11], which can be a constraint to programme participation. MARENASS participants counted more female-headed households than PRONAMACHCS participants. Required labour input is more flexible for MARENASS activities, and participants work in *ayni* groups. However, PRONAMACHCS participants have to provide a minimum of one manday of labour each week, which might be difficult to provide for female-headed households.

Farm households with less assets (land, livestock) and lower agricultural production (in terms of value production and labour used for agriculture), who might be considered the poorest, are not involved in the programmes. However, one can only guess why the poorest families are not reached by the programmes. There may be many reasons why these households are not interested in the programme activities: other priorities, health problems, alcoholism, conformism, a resigned or passive attitude, no "passion" for or interest in agriculture, et cetera.

When it comes to the actual implementation of SWC practices, it is not surprising that programme participants are implementing these practices. The spill-over effect on non-participants is negligible. MARENASS participants and farm households who participate in both programmes implement most terraces and infiltration ditches. MARENASS participants also put more effort (in terms of labour or percentage of farmland with SWC measures) in SWC than PRONAMACHCS participants. Farm households involved in both programmes put most effort in SWC.

The main motivation of programme participants to implement the SWC practices was because it was recommended by the programme, and programme incentives were important to a minor extent for the MARENASS participants. Incentives in the form of contests are an important instrument of MARENASS to motivate farm households. Non-participants mainly installed SWC practices in order to increase agricultural production, but this was an important reason for farm households involved in both programmes as well. Non-participants give lack of knowledge as a main reason for not installing SWC practices, whereas lack of labour and money is the main reason for MARENASS participants. In Pacucha, the two programmes are thus very important in disseminating the knowledge about SWC practices.

7.2.2 Determinants of the adoption process in Pacucha

Programme participation

As depicted in Figure 7.2, the first stage in the adoption process is the decision to participate in a programme. Table 7.4 presents the results of two probit models on participation in PRONAMACHCS activities and participation in MARENASS activities. The results of the bivariate probit with PRONAMACHCS and MARENASS as dependent variables are given in Appendix 7.1. The zero hypothesis that the covariance of the error terms (ρ) of the two probit models for participation in MARENASS or PRONAMACHCS is equal to zero is accepted (Prob.$>\chi^2 = 0.5767$). The decisions on participation in MARENASS or PRONAMACHCS are thus independently taken by the farm household. As PRONAMACHCS and MARENASS are two different programmes (top-down versus bottom-up, conservation versus livelihood improvement), this is plausible.

[11] Female-headed households (on average 3.9 members) are significant smaller than male-headed households (on average 5.4 members) in Pacucha

Table 7.4 *Probit models estimating programme participation, Pacucha (N=176)*

Dependent variable	PRONAMACHCS		MARENASS	
Observations y = 1	60		100	
Independent variables	**β**	***dy/dx***	**β**	***dy/dx***
Constant	-2.666*		-1.926	
Farm area	0.319**	*0.113*	0.195*	*0.076*
Valley	0.684**	*0.242*	0.425	*0.167*
Livestock	3.4E-6	*1.2E-6*	2.4E-5	*9.5E-6*
Family size	-0.056	*-0.020*	0.016	*0.006*
Gender	0.731**	*0.220*	-0.110	*-0.043*
Age	-0.009	*-0.003*	-0.011	*-0.004*
Education	-0.038	*-0.013*	0.057	*0.022*
Dependency ratio	0.929	*0.328*	0.814	*0.319*
Social standing	0.532**	*0.194*	0.598**	*0.226*
Risk taker	-0.249	*-0.088*	-0.464*	*-0.181*
Long term	0.331	*0.117*	-0.099	*-0.039*
Market orientation	-0.450	*-0.159*	1.160**	*0.455*
Presence	0.101	*0.036*	0.147	*0.058*
Off-farm / farm income	-0.066	*-0.023*	-0.193	*-0.076*
Log likelihood	-95.46		-100.74	
Probability > χ^2	0.0015		0.0003	
McFadden R^2	0.155		0.163	
Sensitivity	35.0%		75.0%	
Correctly predicted	69.3%		65.9%	

** significant at 0.1 level   ** significant at 0.05 level*

The amount of farmland and the social standing of the head of household are significant in the three probit models. Additional significant variables differ per probit model. Farm households participating in PRONAMACHCS have more land located in the valley and a male head of household. This confirms the suggestion that due to its compulsory weekly activities, PRONAMACHCS is not very attractive for female-headed farm households (section 7.2.1). Farm households participating in MARENASS are more reluctant to risk and sell a larger part of their agricultural production on the market.

Farm households with an active social standing within the community are more interested to participate in a programme. When a programme starts its activities in a community, the general community meeting (*asamblea general*) is informed first. Though these meetings are open for all community members, only those who are actively involved in community life participate in these meetings and are thus the first to hear about new interventions. Farm households who are socially active often have a more extended network and thus a better access to information about new activities. One might also say that these farm households are part of the “collective”. This stresses the importance that programmes take account of and strengthen the social networks / relationships and social life within (traditional) communities. When community life is well established and well structured, programmes might have more influence. The fact that almost none of the individual household characteristics (like age, family size, education level) is significantly influencing programme participation, strengthen this supposition.

Another result in Table 7.4 is that farm households with more farmland are more likely to participate in agriculture-oriented programmes. In general, farmers with more land are more oriented towards agricultural production. Table 7.3 also showed that the absolute value of agricultural production was lower for non-participants than participants. Farm households who sell their agricultural production on the market are more attracted to MARENASS. Also risk-averse farm households are attracted to MARENASS. This suggests that these farm households consider the activities of MARENASS as risk reducing. They take any opportunity to diversify their income and be part of activities to reduce any risk. PRONAMACHCS participants are male headed and have more land located in the valley. These farm households with more land located in the valley, often live in the lower parts of the watershed, near the main road. According to the farmers, the technical staff of PRONAMACHCS comes once in a while to the villages, stay at the road in the valley and use the horn of their motorbikes to acknowledge the people that they arrived. Apparently not much effort is made to reach the farm households who live in the upper parts of the watershed.

The low scores for the goodness of fit of the estimated models indicate that other factors play an important role in programme participation that are not accounted for in the models. Often, programme staff plays an important role in the notification of the programme activities and the "recruitment" of participants. During informal discussions, farmers mentioned that programme participation was highly influenced, either negatively or positively, by staff members or programme promoters. Some farmers told that in the case of MARENASS, farm households were kept out on purpose by other participants in the beginning. Because of existing conflicts among families and jealousy, the early participants did not want other farm households to participate as well. Farm households also complained about bad performance of the promoters of MARENASS.

Strong rumours exist also about the hidden political agenda of PRONAMACHCS. It is said that the purpose of PRONAMACHCS was to get more contact with and control of the rural population in order to combat the guerilla Shining Path. The former president Fujimori wanted to attract support from the rural people, as this would ensure him of many votes during political elections. Only farm households who voted for Fujimori were allowed to join the programme activities of PRONAMACHCS. According to all these rumours, farm households do not have equal access to the programmes, as is stated by the programmes themselves.

Adoption decision

The second stage in the adoption process is the adoption decision itself. After getting acquainted with the SWC practices through programme activities, farm households decide to implement these technologies on their farm or not. As explained in section 7.1.2, by including programme participation in the adoption equation, a selectivity bias might cause estimation errors. Although it is concluded above that farm households apparently do not have equal access to the programmes, at this stage it is still assumed that programme participation is a self-selection process. To avoid biased estimates, the correction terms (IMRs) were calculated based on the probit models for programme participation, and added in the adoption equation. The results of the linear probability models with the correction terms are presented in Appendix 7.2. To test the zero hypothesis that the coefficients of the IMRs equal zero, the F-statistic was used. The test showed that this zero hypothesis was accepted (Appendix 7.2). There is thus no selectivity bias in the adoption model, and the IMRs can therefore be omitted. Omitting the IMRs in the adoption equation also solves the problem of heteroskedasticity, and now probit models can be used for the estimation of the adoption decision. Table 7.5 shows the results that were obtained for the adoption models without the correction terms.

Table 7.5 *Probit models estimating adoption of SWC practices, Pacucha (N=176)*

Dependent variable	SWC		Bench terrace		Slow-forming terrace		Infiltration ditch	
Observations y=1	**104**		**96**		**25**		**28**	
Variable	**β**	***dy/dx***	**β**	***dy/dx***	**β**	***dy/dx***	**β**	***dy/dx***
Constant	-1.037		-0.264		-3.008**		-2.281**	
PRONAMACHCS	0.842**	*0.289*	0.899**	*0.332*	0.682**	*0.090*	0.114	*0.022*
MARENASS	2.307**	*0.740*	2.279**	*0.746*	1.183**	*0.124*	0.781**	*0.142*
Farm area	0.155	*0.058*	0.168	*0.066*	0.290**	*0.032*	0.186*	*0.035*
Rainfed	-0.087	*-0.033*	-0.441	*-0.174*	-0.562	*-0.061*	0.354	*0.067*
Flat slope	-1.292**	*-0.481*	-0.970**	*-0.382*	-0.678	*-0.074*	-0.815*	*-0.155*
Distance	-0.045	*-0.017*	-0.070	*-0.027*	0.069	*0.007*	-0.035	*-0.007*
No stones	-0.558	*-0.208*	-1.095**	*-0.431*	-0.215	*-0.023*	0.010	*0.002*
Family size	-0.088	*-0.033*	-0.102	*-0.040*	-0.089	*-0.010*	0.001	*1.1E-4*
Gender	-0.022	*-0.008*	-0.285	*-0.110*	0.207	*0.020*	-0.098	*-0.019*
Age	0.017	*0.006*	0.006	*0.002*	0.007	*0.001*	0.003	*0.001*
Education	0.141	*0.052*	0.124	*0.049*	0.245*	*0.027*	0.155	*0.029*
Risk taker	-0.274	*-0.102*	-0.328	*-0.129*	0.097	*0.011*	0.302	*0.058*
Long term	0.106	*0.040*	0.286	*0.112*	-0.396	*-0.043*	-0.147	*-0.028*
Market	-0.568	*-0.221*	-0.909	*-0.358*	1.175	*0.128*	0.140	*0.027*
Log likelihood	-60.10		-63.50		-48.34		-63.66	
Prob. > χ^2	0.0000		0.0000		0.0000		0.0197	
McFadden R^2	0.495		0.476		0.328		0.175	
Sensitivity	89.4%		87.5%		28.0%		14.3%	
Correctly predicted	87.5%		84.7%		86.9%		85.2%	

** significant at 0.1 level   ** significant at 0.05 level*

The programmes have a significant influence on the adoption decision as was expected. External motivation is thus very important for the adoption of SWC practices. The marginal effects of the dummies for the two programmes show that MARENASS has a larger impact than PRONAMACHCS. This is probably due to the different approaches the two programmes used. The contests of MARENASS motivate the farm households to implement the new technologies. However, there is a risk that farm households only implement SWC practices because of the contests, and abandon these practices afterwards. Another reason might be that within the MARENASS approach more attention is paid to instruct farmers how to implement SWC practices, whereas the technical staff of PRONAMACHCS normally supervises the implementation of SWC practices. A third reason can be that MARENASS participants decide themselves where to install the SWC practices, but PRONAMACHCS participants consult with the technical staff.

The need for SWC practices ("demand") is another determining factor: farm households with less flat, thus more sloping farmland, are more inclined to adopt SWC practices. Bench terraces, the most common SWC practices in Pacucha, are implemented on fields with more stones. As stones are required for the construction of the terrace wall, it is easier to implement these terraces on fields where stones are present. At the same time, these stones are "removed" from the fields, facilitating tillage. Farm households with more land opt for less labour-intensive SWC practices like slow-forming terraces and infiltration ditches. These practices are less effective than bench terraces, but since the farm household own more land they might feel less need to invest in their land resources.

When the adoption decision is estimated for a sub-sample of either MARENASS or PRONAMACHCS participants, it appears that in case of the MARENASS participants farm household characteristics influence the adoption decision as well (see Appendix 7.3). MARENASS participants who adopt SWC practices have more sloping land with stones, a smaller family, are older and have a higher education level, are reluctant to risk and have a long term planning horizon. Apparently, MARENASS participants consider SWC practices, especially bench terraces, as risk reducing. Smaller families adopt especially bench terraces. Though these terraces require a huge investment in terms of labour, the terraces are considered as labour-saving, as tillage becomes easier. The adoption decision of PRONAMACHCS participants is not influenced by farm household characteristics, confirming the supposition that the technical staff of PRONAMACHCS highly influence the adoption decision. The fact that the adoption decision of MARENASS participants is influenced by individual household characteristics whereas the adoption decision of PRONAMACHCS participants is not, confirms the more participatory approach of MARENASS, in which participants take initiative and decide themselves whether and where to implement SWC practices (adoption is demand driven). However, in the case of PRONAMACHCS, the programme uses a top-down approach, with technical staff indicating where to implement SWC practices (adoption is supply driven). The adoption is thus not always an individual choice of the PRONAMACHCS participants.

Adoption effort

As the IMRs in the adoption equation were not significant, another two-stage equation can be estimated, in order to analyse the adoption effort. The procedure is similar to the one explained in 7.1.2, except that adoption effort is conditional on adoption decision (there is thus no effort if farm household decided not to adopt SWC practices), and that the adoption effort is estimated for a sub-sample of observations with non-zero values on adoption (i.e. the group of adopters). This is a straight forward Heckman's two-stage estimation model (GREENE, 2003). The results of the probit for the adoption decision (without the IMRs) are used to calculate the IMRs that are inserted into the adoption effort equation to avoid biased estimates. The amount of labour (mandays) and farmland (ha) dedicated to SWC practices are considered as proxies for effort (Table 7.6).

Farm households with more land put more effort both in labour and land. Most labour is applied to fields near the farm house. Surprisingly, farm households with less sloping land invest more labour in SWC practices. Apparently, it is preferred to invest more labour in those fields where it is easy to implement SWC practices instead of where it is needed but more difficult to implement. The question arises then whether the SWC practices are implemented on the right places in an appropriate way. Larger families invest more labour, but have implemented SWC practices on less land. This seems contradictory. Maybe larger households use their labour inefficiently. Higher educated head of households invest less labour, which can be explained by their higher opportunity costs of labour.

Table 7.6 *Regression results of adoption effort of SWC implementation, Pacucha (N=104)*

Dependent variable / Independent variables	Labour (mandays) β	Area (ha) β
Constant	66.47*	-0.035
Farm area	8.21**	0.570**
Rainfed	25.88*	-0.234
Gentle slope	-46.42**	0.202
Steep slope	-30.81	0.339
Distance	-9.56**	-0.040
No stones	22.04	-0.186
Family size	4.46*	-0.129**
Gender	20.23	0.069
Age	-0.62	0.004
Education	-7.94*	0.021
Risk taker	-8.14	0.116
Long term	-8.49	-0.044
Market	-11.40	-0.278
Years SWC	8.17*	0.017
SWC: programme recommended	5.69	0.341
SWC: programme incentives	26.04	0.481*
SWC: agricultural production	5.30	-0.015
SWC: conservation	45.99*	0.398
IMR (SWC = 1)	-39.85**	0.063
Probability > F	0.0007	0.0000
Adjusted R^2	0.247	0.686

** significant at 0.1 level ** significant at 0.05 level*

The motivation of farm household to adopt SWC practices also influences the effort invested in the implementation. Farm households who implement SWC practices for conservation purposes and who decided to adopt SWC at an early stage, invest more labour. However, this did not result in a larger area with SWC practices. Programme incentives are a significant stimulus to increase the area with SWC practices, as these incentives are distributed according to the amount of hectares with SWC practices. This stimulates the quantity of SWC, but one might question the quality and appropriateness of the practices, as the amount of labour is not increased. In short, farm households who adopted SWC practices for conservation purposes, invest more labour which probably results in a higher quality of the practices compared to the farm households who adopted SWC because of the programme incentives.

Determinants of adoption

Table 7.7 summarises the variables that were significant at different stages of the adoption process as estimated for the farm households in Pacucha. The approach of the programme determines which farm households participate. It is difficult for female-headed households to participate in PRONAMACHCS, as they cannot deliver the required manpower every week. MARENASS, on the other hand attracts risk-averse but market oriented farm households. As both programmes were recently present in Pacucha, social standing of the farm household was very important for programme participation. The adopters of SWC practices are the programme participants, who are actively involved in the social community life, have more land and are more oriented towards agriculture. The adopters are also those farm households who experience the need for SWC practices, as they have more sloping land. Programme incentives result in more area with SWC practices, but not in more labour invested, so the question arises whether these SWC practices are of good quality and will be maintained. Apparently, most labour is invested in the near fields, but less labour is invested in the sloping fields.

Table 7.7 *Determinants of the adoption process in Pacucha*

Programme participation			
In general:	PRONAMACHCS:	MARENASS:	
Social standing (++)	Gender (male, ++)	Market oriented (++)	
Farm area (++)	Land in valley (++)	Risk taker (-)	
Adoption decision			
In general:	Bench terraces:	Slow-forming terrace:	Infiltration ditch:
PRONAMACHCS (++)	Stones in field (++)	Farm area (++)	Farm area (++)
MARENASS (++)		Education (+)	
Sloping land (++)			
Effort			
In general:	Labour:	Area:	
Farm area (++)	Sloping land (--)	Family size (--)	
	Distance fields (--)	Programme incentives (+)	
	Rainfed (+)		
	Family size (+)		
	Education (-)		
	Years SWC (+)		
	Conservation (+)		

7.2.3 Adoption process over time in Pacucha

To get a better insight in the adoption process throughout the years, the farm households are compared according to the year when they started implementing SWC practices. Table 7.8 presents the results of this comparison. Only variables that were significantly different are shown.

Before 1998, SWC practices were only adopted in Tahuantinsuyo and Santa Elena. At that time only PRONAMACHCS was present in these two communities. MARENASS started in 1998 in the five peasant communities. In 1998, SWC practices were adopted in Jose Olaya, Tahuantinsuyo and to a smaller extent in Churrubamba. This was explained by farmers who complained that in the first years of MARENASS there was only one programme promoter who lived in Jose Olaya, and who never visited the villages Santa Elena and Manchaybamba. Later, MARENASS contracted more programme promoters, one living in Santa Elena. After his appointment in 2000, more farm households were involved in the programme activities, and SWC practices were also implemented in Santa Elena and Manchaybamba. Programme staff or promoters thus have an important impact on the timing and extent involving farm households and disseminating new technologies.

Looking at farm household characteristics, the only differences that are significant are the dummies for social standing, risk taking behaviour and long term planning. Farm households adopting SWC practices later, are more risk-averse and less long term oriented. The early adopters are definitely more concerned with the long term and have more often an important social standing. The early adopters are involved in both programmes and are most frequently in contact with programme staff.

This confirms that programmes are very important in disseminating new technologies. Whether a farm household is an innovator or laggard depends on its time horizon and risk behaviour. Early adopters also have more land. Non-adopters have significantly less land and livestock, and also spend less time in agriculture. Non-adopters and late adopters have more farmland that is located in the valley. For them, there is thus also less necessity to implement SWC practices. Besides, non-adopters have the least farmland with gentle slopes, where most of the SWC practices are installed.

Table 7.8 *Variables explaining adoption process over time in Pacucha*

Variable [A]	**prob>F**	**First year of implementation SWC practices** no SWC N=72	< 1998 N=4	1998 N=13	1999 N=24	2000 N=23	2001 N=38
Community							
Jose Olaya	0.0002	0.00	0.00	0.31	0.13	0.09	0.03
Manchaybamba	0.0023	0.40	0.00	0.00	0.08	0.26	0.39
Tahuantinsuyo	0.0001	0.40	0.75	0.62	0.04	0.22	0.18
St. Elena	0.0152	0.14	0.25	0.00	0.29	0.39	0.34
Churrubamba	0.0000	0.06	0.00	0.08	0.46	0.04	0.05
Farm household characteristics							
Social standing	0.0002	0.14	0.75	0.46	0.54	0.43	0.39
Risk taker	0.0510	0.58	0.50	0.38	0.63	0.48	0.29
Long term planner	0.0634	0.51	0.75	0.69	0.58	0.52	0.29
Farm household assets							
Total farm area (ha)	0.0638	0.71	1.54	1.63	1.47	1.41	1.03
Total farm labour (mandays)	0.0632	41	62	76	72	69	57
Off-farm income (S/.)	0.0051	1837	1560	4109	1722	2174	1546
Value livestock (S/.)	0.0294	2129	3825	2299	3557	2606	2532
Farmland characteristics							
Farmland in valley (ratio)	0.0741	0.40	0.34	0.34	0.16	0.35	0.43
Farmland gentle slope (ratio)	0.0462	0.35	0.60	0.46	0.63	0.50	0.47
Programme involvement							
Non-participants	0.0000	0.69	0.25	0.00	0.04	0.04	0.03
PRONAMACHCS	0.0034	0.14	0.75	0.08	0.08	0.17	0.05
MARENASS	0.0000	0.10	0.00	0.15	0.58	0.48	0.71
Both programmes	0.0000	0.07	0.00	0.77	0.29	0.30	0.21
Contact frequency PRONAMACHCS	0.0001	5.21	26.50	32.46	14.63	18.48	9.26
Contact frequency MARENASS	0.0000	2.94	0.00	44.15	31.75	22.78	25.34
SWC implementation							
Slow forming terrace	0.0000	0.00	0.00	0.54	0.33	0.17	0.16
Bench terrace	0.0000	0.00	0.75	0.92	0.96	0.87	0.95
Infiltration ditch	0.0000	0.00	0.25	0.38	0.25	0.35	0.21
Labour invested SWC (mandays)	0.0000	0.00	21.50	87.15	44.33	53.48	45.66
Farmland with SWC (ha)	0.0000	0.00	0.43	0.86	0.91	0.81	0.39

[A] Variables without units are dummy variables. The average values presented in the table are ratios.

7.3 Empirical results on adoption behaviour in Piuray-Ccorimarca

7.3.1 Comparing programme participants in Piuray-Ccorimarca

The programmes PRONAMACHCS and ARARIWA are intervening in the watershed Piuray-Ccorimarca for about 20 years. Most farm households are, or have been, involved in these programmes, in contrary to the farm households of Pacucha. Almost all farm households included in the survey participated in the PRONAMACHCS activities. This might be due to a sampling error, as students of PRONAMACHCS carried out the survey. But on the other hand, PRONAMACHCS has been present in this area for 20 years already and the majority of the farm households are indeed participating.

Table 7.9 shows the significant different characteristics for the sub-samples according to programme involvement in Piuray-Ccorimarca. In contrast to the results of programme participants in Pacucha, the different groups in Piuray-Ccorimarca did not show many significant differences. This is due to the fact that there is only a small group of farmers not participating in any programme. Only 4 farm households participate only in ARARIWA and not in PRONAMACHCS. Therefore, the results on ARARIWA participants might be ignored, as one might question the representativeness of this small group.

Table 7.9 *Comparison of sub-sample of programme involvement in Piuray-Ccorimarca*

Variable [A]	Significant difference	Sub-sample: No programme	PRONAM.	ARARIW.	Both	*All*
	Prob.>F	N = 13	N = 38	N = 4	N = 133	*N = 188*
Farm household characteristics						
Family size (members)	0.06	4.08	4.18	5.75	4.94	*4.74*
Risk taker	0.01	0.85	0.76	0.50	0.53	*0.60*
Farm household assets						
Value agricultural production (S/.)	0.00	2054	2929	774	1170	*1578*
Total farm area (ha)	0.00	1.21	1.25	0.44	0.54	*0.73*
Total farm labour (mandays)	0.01	263	157	78	87	*113*
Off-farm income (S/.)	0.09	1832	3088	273	4541	*3969*
SWC implementation						
Slow forming terrace	0.06	0.00	0.37	0.25	0.36	*0.34*
SWC practice	0.00	0.15	0.61	0.25	0.65	*0.60*
Motivation						
SWC: programme recommended	0.01	0.69	0.53	0.25	0.32	*0.38*
SWC: because of incentives	0.00	0.54	0.26	0.75	0.07	*0.15*
No SWC: lack of labour / money	0.02	0.38	0.21	0.25	0.10	*0.14*

[A] Variables without units are dummy variables. The average values presented in the table are ratios.

The only household characteristics that differ significantly are family size and risk behaviour. As in Pacucha, programme participants are more risk-averse than non-participants. Programme participants also have larger families. Farm households who participate in ARARIWA have less land and less agricultural production than farm households who only participate in PRONAMACHCS and non-participants.

Programme participants have significantly more slow-forming terraces than non-participants, so also in Piuray-Ccorimarca the programmes play an important role in the dissemination of SWC practices. The values for bench terraces and infiltration ditches do not differ significantly among the different programme participants. Bench terraces are hardly introduced in this area, and infiltration ditches are installed on the communal pasture areas. Programme incentives were an important reason to implement SWC practices for ARARIWA participants and (presently) non-participants. ARARIWA used to pay farmers to install SWC practices, which they therefore considered as an off-farm income opportunity, instead of a conservation activity. Most respondents (both programme participants and non-participants) mentioned lack of labour and money as constraints for further implementation of SWC practices. As SWC activities have been carried out for 20 years already, lack of knowledge is not an issue anymore.

7.3.2 Determinants of the adoption process in Piuray-Ccorimarca

Programme participation

In order to explain the adoption process in Piuray-Ccorimarca, the same procedure is followed as in section 7.2.2. Appendix 7.4 shows the results of the bivariate probit with PRONAMACHCS and Arariwa as dependent variables. The zero hypothesis that the covariance of the error terms (ρ) of the two probit models for participation in PRONAMACHCS and Arariwa is equal to zero is rejected (Prob.>χ^2 = 0.0001). The decisions to participate in PRONAMACHCS or Arariwa are thus related. This seems reasonable as the two programmes are similar to each other. As these decisions are dependent, they are combined in the analysis for Piuray-Ccorimarca, considering only the decision of a farm household whether to participate in a programme, without making the distinction whether the household participates in PRONAMACHCS or Arariwa. Table 7.10 presents the results of the single probit model for programme participation. The variable gender was omitted in the probit model, as it was a perfect predictor for programme participation.

Table 7.10 *Probit model estimating programme participation, Piuray-Ccorimarca (N=188)*

Dependent variable	**Programme**	
Observations y=1	**175**	
Independent variables	**β**	***dy/dx***
Constant	1.521	
Farm area	-0.182	*-0.009*
Valley	-0.284	*-0.014*
Livestock	2.2E-4	*1.1E-5*
Family size	0.135	*0.007*
Age	0.008	*3.8E-4*
Education	-0.254*	*-0.012*
Dependency ratio	-1.668*	*-0.081*
Social standing	0.510	*0.024*
Risk taker	-1.088**	*-0.050*
Long term	-0.209	*-0.010*
Market orientation	0.127	*0.006*
Presence	0.078	*0.004*
Off-farm / farm income	0.372*	*0.018*
Log likelihood	-35.42	
Probability > χ^2	0.0340	
McFadden R^2	0.251	
Sensitivity	100.0%	
Correctly predicted	93.6%	

** significant at 0.1 level*   *** significant at 0.05 level*

Risk behaviour is the most significant explaining variable in the model. Other significant variables are education level, dependency ratio and the income ratio. Apparently, the high educated and risk taking households do not expect any benefit from participating in programme activities. ARARIWA participants have less land but larger households, and are more market oriented, whereas PRONAMACHCS participants are characterised by their dependence on off-farm income (Appendix 7.4). Note that in Piuray-Ccorimarca individual household characteristics influence programme participation, in contrast to Pacucha. As the programmes are present for 20 years, access to the programme activities may be more equal for the farm households, as they are all informed about these activities, than in Pacucha. Also, Piuray-Ccorimarca is richer and more market-oriented, and an individual demand is created for programme activities. The collective aspect of community life became less important. Especially the farm households with lower opportunity costs of labour (lower education level) and that are risk-averse, have interest in the programme activities.

As in Pacucha, the probit model for programme participation in Piuray-Ccorimarca has low scores for the goodness of fit. The rumours about the political intentions of PRONAMACHCS apply here as well. Besides that, the programmes exist for a long period, and the diffusion of their activities is widespread among the population. Almost all farm households are participating in a programme so hardly any distinction can be made between participants and non-participants.

Adoption decision

Appendix 7.5 contains the linear probability models including the IMRs estimating the adoption decision. As in the adoption analyses for Pacucha, the F-tests accepted the zero hypothesis of the correction terms (IMRs) being equal to zero. The results of the probit model (without IMRs) for the adoption decision are given in Table 7.11.

Programmes positively stimulate adoption of SWC practices, but not the specific practices separately. Especially farm households with more rainfed land (without access to irrigation) have SWC practices. These rainfed areas are mainly the sloping areas in the upper part of the watershed where the programmes put most effort in SWC practices (mainly infiltration ditches and slow forming terraces). Farm households, who are younger and have a long term vision, implement bench terraces. Farm households with more land install the less intensive slow-forming terraces. The variable programme was dropped in the equation for slow-forming terraces, as all farm households without slow-forming terraces did not participate in any programme. The infiltration ditches are installed on the fields that are furthest away.

The scores for goodness of fit of the probit models on adoption are low, whereas the results for Pacucha were fairly convincing. In Piuray-Ccorimarca it is more common that the technical staff of the programmes (PRONAMACHCS in specific) decide where to implement SWC practices. The adoption decision is not always made at farm household level, as is assumed in the model. Indeed, cases were known where the programme decided to implement SWC practices on fields of which the owners were not agreed on. These farm households neglected or even removed the SWC practices at their fields. Another explanation of the low scores is that in many cases the SWC practices were implemented a long time ago. The farm household data that was obtained with the survey in 2002 is not representative any more for the moment when the adoption decision was taken. This probably distorts the results.

Table 7.11 *Probit model estimating adoption of SWC practices, Piuray-Ccorimarca (N=188)*

Dependent variable	SWC		Bench terrace		Slow-forming terrace		Infiltration ditch	
Observations y=1	**112**		**28**		**63**		**43**	
Variable	**β**	***dy/dx***	**β**	***dy/dx***	**β**	***dy/dx***	**β**	***dy/dx***
Constant	-1.201		-0.018		0.359		-1.788*	
Programme	1.759**	*0.561*	0.588	*0.088*	†		0.579	*0.121*
Farm area	0.098	*0.038*	-0.067	*-0.014*	0.300**	*0.111*	-0.228	*-0.061*
Rainfed	0.809**	*0.313*	-0.671*	*-0.137*	0.483*	*0.179*	1.175**	*0.315*
Flat slope	0.055	*0.021*	-0.393	*-0.080*	0.166	*0.062*	0.184	*0.049*
Distance	0.026	*0.010*	-0.052	*-0.011*	0.005	*0.002*	0.311**	*0.083*
No stones	-0.351	*-0.136*	-0.425	*-0.087*	0.070	*0.026*	-0.351	*-0.094*
Family size	0.048	*0.019*	-0.047	*-0.010*	0.064	*0.024*	-0.048	*-0.013*
Gender	0.080	*0.031*			-0.642	*-0.251*	0.171	*0.043*
Age	-0.016*	*-0.006*	-0.023**	*-0.005*	-0.012	*-0.004*	-0.009	*-0.002*
Education	-0.077	*-0.030*	-0.101	*-0.021*	-0.150	*-0.056*	0.036	*0.010*
Risk taker	0.340	*0.132*	0.057	*0.012*	0.165	*0.061*	0.489*	*0.126*
Long term	0.084	*0.033*	0.779**	*0.142*	-0.199	*-0.074*	0.035	*0.009*
Market	-0.245	*-0.095*	0.401	*0.082*	0.016	*-0.006*	-0.176	*-0.047*
Log likelihood	-110.99		-70.79		-103.66		-84.47	
Prob. > χ^2	0.0026		0.0240		0.0452		0.0016	
McFadden R^2	0.125		0.142		0.093		0.165	
Sensitivity	86.6%		10.0%		31.8%		23.3%	
Correctly predicted	69.7%		84.6%		70.9%		78.2%	

** significant at 0.1 level* *** significant at 0.05 level*

† Programme = 1 predicts failure perfectly: variable programme was dropped and 13 observations neglected.

Adoption effort

Also for Piuray-Ccorimarca the adoption effort can be estimated with a two-stage equation since there is no selectivity bias in the probit model for adoption. As in section 7.2.2., the results of the probit for the adoption decision (without the IMRs) are used to calculated the IMRs that are inserted into the adoption effort equation to avoid biased estimates.

Table 7.12 gives the results on estimation of adoption effort in Piuray-Ccorimarca. Larger farm households that are younger and have a long term time horizon invest more labour and land in the implementation of SWC practices. Farm households with more rainfed land, implemented the SWC practices on more fields.

Table 7.12 *Regression results of effort of SWC implementation, Piuray-Ccorimarca (N=112)*

Dependent variable / Independent variables	Labour β	Area β
Constant	-36.64	-0.304
Farm area	5.38	0.081**
Rainfed	40.51	0.311**
Gentle slope	5.28	-0.106
Steep slope	43.52	-0.017
Distance	-6.19	-0.032
No stones	-2.38	-0.140
Family size	11.04**	0.072**
Gender	-8.70	-0.142
Age	-2.38**	-0.012**
Education	-9.55	0.016
Risk taker	-14.05	0.061
Long term	45.60**	0.189**
Market	40.31	-0.200
Years SWC	3.30	0.020*
SWC: programme recommended	-4.05	-0.023
SWC: programme incentives	25.50	0.074
SWC: agricultural production	-0.97	0.115
SWC: conservation	-18.53	0.032
IMR (SWC = 1)	159.39**	0.811**
Probability > F	0.1150	0.0008
Adjusted R^2	0.075	0.308

** significant at 0.1 level   ** significant at 0.05 level*

Determinants of adoption

Table 7.13 summarises the variables that were significant at the three stages of the adoption process, as estimated for the farm households in Piuray-Ccorimarca.

Table 7.13 *Determinants of the adoption process in Piuray-Ccorimarca*

Programme participation			
Education level (-)			
Dependency ratio (-)			
Risk taker (--)			
Off-farm income (+)			
Adoption decision			
In general:	Bench terraces:	Slow-forming terrace:	Infiltration ditch:
Rainfed (++)	Long term (++)	Farm area (++)	Rainfed (++)
	Age (--)		Distance (++)
			Risk taker (+)
Effort			
In general:	Labour:	Area:	
Family size (++)		Farm area (++)	
Age (--)		Rainfed (++)	
Long term (++)		Years SWC (+)	

Programme participants are farm households that are risk-averse and have a low education level, and are thus assumed to have a low opportunity cost of labour. Farm households who depend more on off-farm income or have a lower dependency ratio also participate. Programme participation is only for significant in the probit model for SWC practices. However, most farm households in the sample are programme participants. Younger farm households with a long term vision adopt bench terraces. Slow-farming terraces are installed on farms with more land, and infiltration ditches are installed on rainfed land at a larger distance from the houses. Larger and younger farm households with a long term time horizon also make most effort in the implementation of the SWC practices.

Adoption process over time in Piuray-Ccorimarca

The adoption process in Piuray-Ccorimarca started already in the 1980s. The data collected in the survey are from 2002, and as these data are not representative for the characteristics of farm households at the time they adopted SWC practices, no clear explanations or trends could be found for the adoption process over time in this area.

7.4 Factors influencing farmers' adoption behaviour of SWC practices

In both watersheds the presence of agriculture-oriented programmes was an important factor stimulating the adoption of SWC practices. In general one can conclude that the adopters of SWC practices are the programme participants who experience the need for SWC practices. Farm households participating in the programmes are risk-averse. Programme participation can be considered a risk-reducing strategy, as these programmes help the farm households to diversify income and agriculture. The intervention strategies of the programmes partly define which farm households participate in the programme, and as a consequence the adoption pattern. For example, PRONAMACHCS organises weekly activities, and a participating farm household has to "deliver" labour of at least one member every week. This is difficult for female-headed households, as they are more labour constrained. However, the low scores on goodness of fit of the participation equations were striking. This suggests that in both watersheds, other factors play a role in the decision to participate in a programme, that were not accounted for. Farm households mentioned the rumours about the hidden agendas of the programmes and some participants. Programme staff mentioned the conformism and especially alcoholism of the (often male) head of the farm households as a reason of disappointing results.

In Pacucha, the diffusion or adoption process seems to be at an earlier stage than in Piuray-Ccorimarca where the diffusion of SWC practices is about complete. In Pacucha lack of knowledge is still hampering the adoption process and programme incentives are an important stimulus for the adoption effort, in contradiction to Piuray-Ccorimarca. Farm households who are actively involved in community life are the first to hear about new interventions and to participate. These farm households are often the leaders and innovators within the community. When an intervention or diffusion of a new technology is still in an early stage, these households participate in the programmes, and are the first adopters. This is consistent with the diffusion theory of Rogers (1962). Due to the long intervention period in Piuray-Ccorimarca, all farm households are aware of the programmes and the SWC practices. The social activity of the farm household does not play an important role anymore in the decision on programme participation. Instead, programme participation is more demand-driven in Piuray-Ccorimarca, as participation is determined by household characteristics like education and risk behaviour.

An important difference between the two watersheds, is that Pacucha is still less developed and less market oriented, whereas farm households in Piuray-Ccorimarca have more assets, are better educated and live close to the booming (tourist) market in Cusco where they can sell their products and have more off-farm income opportunities. Opportunity cost of labour is therefore an important factor in decision-making in Piuray-Ccorimarca. When a farm household has a higher opportunity cost of labour (higher educated, smaller households and thus less labour available) it is less likely to participate in a programme, and invest much labour in the implementation of SWC practices. This is not an issue (yet) in Pacucha.

The results of Pacucha suggest that programme staff of PRONAMACHCS decide on the location of SWC practices and thus influence the adoption decision. For these participants the adoption decision is mainly determined by the land characteristics (rainfed fields and steep slopes), but hardly by farm household characteristics. MARENASS participants decide themselves whether to implement which SWC practice (i.e. the adoption decision). These findings are explained by the approaches of the programmes: MARENASS applies a more participatory approach, emphasising knowledge development and empowerment of its participants. PRONAMACHCS and Arariwa, on the other hand, apply a more top-down approach, as they consider lack of knowledge as most important constraint for sustainable agriculture and rural development, and knowledge transfer thus as a solution (see section 4.4.1). A participatory approach, like MARENASS, is considered to lead to a more sustainable adoption of SWC practices than a top-down approach (Pretty and Shah, 1997). Farm households in Pacucha (mainly MARENASS participants) prefer to invest more in the less sloping fields near the houses, whereas in Piuray-Ccorimarca more effort is put in the rainfed fields. If farm households individually decide on the adoption of SWC practices, they prefer to invest in those fields where SWC might be less needed considering soil conservation, but where implementation is easier and cultivation is more intensive. If a programme influences the adoption decision, most effort is put in the most degraded areas (rainfed land, with steep slopes and at a larger distance) that are cultivated extensively. From a SWC perspective the latter is preferred, but from economic point of view the first practice is probably more interesting for the farm household.

Though programmes have a large influence on the adoption behaviour of farm households, the programme incentives that are provided seem to be less important. The results in Pacucha indicate that programme incentives stimulate an increase of the area with SWC practices, this is not accompanied with an increase of labour invested in the implementation. This is probably due to the contests organised by MARENASS. A jury judges only the quantity of SWC practices implemented by a farm household, not the quality. One might thus doubt the quality and appropriateness of the SWC practices that are installed during these contests.

7.5 Conclusions

This case study shows that external persuasion through programmes promoting SWC is the key driver of the adoption process of SWC practices. Especially in an early stage of technology diffusion, the targeting policy of programmes defines the adoption pattern. Though the importance of SWC-oriented programmes on the adoption process is acknowledged by some (e.g.: Cramb et al., 1999; Tenge et al., 2004), this is rarely taken into account in these analyses to our surprise. Not considering the decision on programme participation might lead to biased results on adoption behaviour.

The social network of a farm household is an important factor determining programme participation and subsequently adoption behaviour. This is also found by others (Nowak, 1987; Baidu-Forson, 1999; Jagger and Pender, 2003). Especially at the start of the intervention and diffusion process, the social network is important in order to be informed early. Once the diffusion process is spreading, the individual demand of households for programme participation becomes more important than the social network.

In contrast to findings of others (e.g.: Feder et al., 1982; Marsh, 1998; Asfaw and Admassie, 2004), farm household characteristics like education or human capital did not seem to have a large influence on adoption behaviour, or they had a negative influence. Better educated farmers have a higher opportunity cost of labour, and are therefore less interested in the low-earning SWC activities (Posthumus and Graaff, 2005). Risk behaviour is an important factor determining adoption behaviour. It is often stated that, since SWC practices imply a large investment, risk-averse farm households are reluctant to adopt these practices (e.g.: Feder et al., 1982; Sinden and King, 1990; Marra et al., 2003). In this case study the contrary is found: as risk-averse farm households are more interested in programme participation, these risk-averse farmers also adopt SWC practices. However, it is not possible to generalise adoption processes, as these depend on the technologies, as well as the socio-economic and institutional context (Graaff et al., 2005).

APPENDIX 7.1

Bivariate probit for programme participation in Pacucha

Dependent variable Independent variables	PRONAMACHCS β	MARENASS β
Constant	-2.634*	-1.938
Farm area	0.318**	0.193*
Valley	0.684**	0.427
Livestock	3.3E-6	2.6E-5
Family size	-0.057	0.015
Gender	0.727**	-0.115
Age	-0.009	-0.011
Education	-0.036	0.062
Dependency ratio	0.931	0.813
Social standing	0.532**	0.605**
Risk taker	-0.254	-0.464**
Long term	0.327	-0.097
Market orientation	-0.445	1.169**
Presence	0.099	0.146
Off-farm / farm income	-0.063	-0.189
Log likelihood = -196.05 Probability > χ^2 = 0.0009		
rho = -0.079 *Likelihood-ratio test of rho = 0 :* Probability > χ^2 = 0.5767		

** significant at 0.1 level   ** significant at 0.05 level*

APPENDIX 7.2

Determinants of adoption decision in Pacucha, linear probability models with correction terms

Dependent variable	SWC		Bench terrace		Slow-forming terrace		Infiltration ditch	
Observations y=1	104		96		25		28	
Variable	β	Robust St.err.	β	Robust St.err.	β	Robust St.err.	β	Robust St.err.
Constant	-0.018	0.206	0.140	0.214	0.052	0.203	-0.029	0.196
PRONAMACHCS	-0.047	0.449	0.344	0.521	-0.057	0.552	-0.175	0.703
MARENASS	0.958**	0.384	0.720*	0.417	0.346	0.489	0.199	0.527
Farm area	0.033	0.033	0.019	0.038	0.085*	0.044	0.073	0.053
Rainfed	-0.019	0.093	-0.079	0.091	-0.092	0.083	0.062	0.090
Flat slope	-0.259**	0.081	-0.230**	0.084	-0.058	0.054	-0.091	0.071
Distance	-0.012	0.018	-0.017	0.015	0.004	0.011	-0.008	0.013
No stones	-0.109	0.097	-0.212**	0.101	-0.022	0.077	-0.004	0.092
Family size	-0.027	0.016	-0.025	0.017	-0.019	0.018	0.004	0.022
Gender	0.088	0.133	-0.052	0.150	0.095	0.165	-0.018	0.188
Age	0.003	0.002	0.002	0.003	0.000	0.002	0.000	0.003
Education	0.019	0.025	0.027	0.026	0.025	0.035	0.016	0.033
Risk taker	-0.026	0.082	-0.043	0.083	0.002	0.077	0.079	0.072
Long term	0.034	0.078	0.024	0.078	-0.022	0.090	-0.029	0.097
Market	-0.271	0.268	-0.191	0.291	0.053	0.372	-0.057	0.395
IMR(PRONAMACHCS=0)	0.062	0.341	-0.169	0.377	0.292	0.421	-0.002	0.478
IMR(PRONAMACHCS =1)	0.134	0.250	-0.102	0.305	-0.029	0.305	0.182	0.436
IMR(MARENASS=0)	-0.348	0.238	-0.221	0.247	-0.051	0.298	-0.002	0.302
IMR(MARENASS=1)	-0.033	0.248	0.113	0.278	-0.221	0.312	-0.093	0.340
R^2	0.564		0.546		0.273		0.155	
Prob. > F	0.0000		0.0000		0.0000		0.0897	
F-test IMRs = 0	1.34		1.21		1.05		0.29	
(Prob.> F)	(0.2573)		(0.3106)		(0.3841)		(0.8817)	

** significant at 0.1 level* *** significant at 0.05 level*

APPENDIX 7.3

Determinants of adoption decision for sub-samples of programme participants, Pacucha

Variable	MARENASS (N=100)				PRONAMACHCS (N=60)			
	SWC	**bench terrace**	**slow-forming terrace**	**infiltr. ditch**	**SWC**	**bench terrace**	**slow-forming terrace**	**infiltr. ditch**
Constant	1.034	3.373*	-2.389**	-1.354	-0.471	2.237	-2.183	-2.415
PRONAMACHCS	-0.154	-0.095	0.630*	-0.059				
MARENASS					1.204**	0.903*	1.276*	0.767
Farm area	0.373	0.316*	0.241**	0.242**	0.289	0.336*	0.624**	0.243
Rainfed	-0.868	-0.304	-0.426	-0.268	-0.988	-1.756**	0.184	0.583
Flat slope	-3.808**	-2.279**	-0.707	-0.517	-1.942**	-1.461**	-0.203	-0.938
Distance	0.602	0.069	0.106	-0.006	0.187	0.008	-0.134	-0.076
No stones	-2.378**	-2.353**	-0.387	-0.173	-1.037	-1.334	0.188	-1.043
Family size	-1.120**	-0.569**	-0.095	0.025	-0.226	-0.111	-0.201	-0.102
Gender	-2.255	-2.029	0.166	-0.428	0.480	-0.344	-	-0.040
Age	0.211**	0.072**	0.017	0.004	0.045	-0.006	0.015	0.021
Education	1.100**	0.680**	0.315**	0.209	0.249	0.140	0.252	0.225
Risk taker	-1.239*	-0.746*	-0.008	0.281	-0.674	-0.129	-0.582	0.300
Long term	1.185*	0.597	-0.204	-0.186	0.912	0.707	-0.584	0.628
Market	0.052	-0.596	1.500*	0.413	-1.156	-1.372	-1.038	-1.715
Log likelihood	-17.83	-26.62	-42.25	-47.32	-18.74	-22.97	-19.54	-23.97
Prob. > χ^2	0.0003	0.0003	0.0375	0.4319	0.0047	0.0111	0.0107	0.5191
McFadden R^2	0.514	0.416	0.217	0.123	0.445	0.373	0.400	0.202
Sensitivity	96.6%	94.0%	34.8%	13.0%	91.1%	92.9%	53.3%	16.7%
Correct	92.0%	84.0%	81.0%	77.0%	81.7%	85.0%	78.6%	76.7%

** significant at 0.1 level* *** significant at 0.05 level*

APPENDIX 7.4

Bivariate probit for programme participation in Piuray-Ccorimarca

Dependent variable **Independent variables**	**PRONAMACHCS** **β**	**Arariwa** **β**
Constant	2.905*	0.975
Farm area	-0.170	-0.387**
Valley	-0.560	0.291
Livestock	1.2E-4	1.3E-5
Family size	0.019	0.226**
Age	0.004	-0.012
Education	-0.316**	-0.183*
Dependency ratio	-0.483	-0.744
Social standing	0.531	0.309
Risk taker	-0.587	-1.089**
Long term	-0.341	0.365
Market orientation	0.454	1.202**
Presence	-0.025	0.001
Off-farm / farm income	-0.170**	0.084
Log likelihood = -124.96 Probability > χ^2 = 0.0117		
rho = 0.723 *Likelihood-ratio test of rho = 0 :* Probability > χ^2 = 0.0001		

** significant at 0.1 level   ** significant at 0.05 level*

APPENDIX 7.5

Determinants of adoption decision in Piuray-Ccorimarca, linear probability models with correction terms

Dependent variable	**SWC**		**Bench terrace**		**Slow-forming terrace**		**Infiltration ditch**	
Observations y=1	**112**		**28**		**63**		**43**	
Variable	**β**	**Robust St.err.**	**β**	**Robust St.err.**	**β**	**Robust St.err.**	**β**	**Robust St.err.**
Constant	-0.291	0.519	0.573*	0.293	0.078	0.449	-0.682	2.479
Programme	1.014**	0.404	-0.164	0.224	0.507	0.337	0.876**	0.383
Farm area	0.041	0.039	-0.003	0.020	0.079**	0.033	-0.038	0.026
Rainfed	0.276**	0.100	-0.143**	0.069	0.152	0.098	0.324**	0.092
Flat slope	0.019	0.102	-0.086	0.078	0.035	0.101	0.075	0.077
Distance	0.004	0.047	-0.010	0.026	-0.005	0.041	0.094*	0.049
No stones	-0.104	0.110	-0.094	0.087	0.012	0.106	-0.078	0.091
Family size	0.007	0.018	-0.012	0.012	0.022	0.020	-0.024	0.017
Gender	0.040	0.186	0.189**	0.069	-0.255	0.194	0.032	0.131
Age	-0.006*	0.003	-0.006**	0.002	-0.003	0.003	-0.003	0.003
Education	-0.017	0.033	-0.032	0.021	-0.035	0.027	0.016	0.025
Risk taker	0.158*	0.093	0.033	0.065	0.031	0.093	0.160**	0.078
Long term	0.032	0.091	0.175**	0.063	-0.057	0.092	0.000	0.071
Market	-0.100	0.173	0.088	0.124	0.018	0.162	-0.089	0.136
IMR(Programme =0)	-0.281	0.274	0.193	0.124	-0.091	0.202	-0.429	0.265
IMR(Programme =1)	-0.371	0.320	-0.145	0.194	0.031	0.289	-0.398	0.271
R^2	0.164		0.135		0.135		0.189	
Prob. > F	0.0000		0.0509		0.0000		0.0030	
F-test IMRs = 0	1.21		1.47		0.11		2.23	
(Prob.> F)	(0.3016)		(0.2323)		(0.8985)		(0.1108)	

** significant at 0.1 level* *** significant at 0.05 level*

Chapter 8

The effect of terraces on factor productivity

A revised version of this chapter is in preparation as:
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8 The effect of terraces on factor productivity

The implementation of soil and water conservation (SWC) practices, especially terraces, requires a huge investment of labour and capital. In Chapter 7 it was concluded that farm households who participate in an SWC-promoting programme, and who have sloping farmland, adopt SWC practices. Hence, external persuasion is important in the decision-making of farmers to invest in SWC. However, whether the investment in SWC pays off on long-term, depends on the impact of SWC practices on the productivity of the production factors. Productivity change is an important potential aspect of technological change (Jayasuriya, 2003). Production efficiency is improved when the productivity of the scarcest production factor is increased. Increased productivity or output stability contribute to the willingness of poor farmers to adopt resource-conserving practices that are economically viable in the farmers' context of risk and resource constraints (Scherr, 2000). In this chapter it will be explored how terraces (that is, bench terraces and slow-forming terraces) affect the efficiency of agricultural production. The effect of terraces on the productivity of land, labour and fertilisers at farm household level is determined by estimating production functions.

Most research on the effect of SWC practices considers only land or soil productivity (e.g.: Byiringiro and Reardon, 1996; Hellin and Haigh, 2002; Shiferaw et al., 2003), and a few also take the effect of SWC on fertiliser productivity into account (e.g.: Zougmoré et al., 2004). In Chapter 5 it was concluded that yield increase at field level due to terraces is negligible if it is not accompanied with a change in crop management. It is also shown that SWC practices increase the efficiency of fertilisers and that due to the complementary effect of these two technologies a significant higher yield can be obtained. Due to the reduced runoff (and thus retention of fertilisers) and the improved soil-moisture content, the effect of fertilisers on crop production is increased. Often, the application of fertilisers is limited due to a lack of capital to buy these fertilisers. In many cases, the purchase of chemical fertilisers is a risky investment for the farm household. If the returns or productivity of fertilisers can be increased by SWC, this investment becomes more rewarding.

Less research is done on the effect of SWC on labour productivity. However, in rural areas in developing countries (LDCs), labour productivity is important for a farm household. As market prices for agricultural products are low, many farm households in the Andes rely (partly) on non-farm activities for cash income (see Chapters 3 and 4). The ability of farm households to respond to prices in order to receive the highest returns for their resources and products, is constrained by market failures (Janvry et al., 1991). Labour availability and its allocation between different activities including leisure, are important for the household's income and welfare. Though labour is to spend on the farm to assure the household's food consumption, a household cannot afford to use all its labour resources for farm activities. Off-farm income is also indispensable for the livelihood of farm households, and increases their food security (Reardon et al., 2001; Ruben and Berg, 2001). Farm households in the Andes therefore allocate their resources (land, labour, capital) to different types of income activities, like food crops, cash crops, off-farm employment. Off-farm labour productivity is relatively fixed by means of market wages, but the farm labour productivity is flexible. Farm labour productivity can be increased either by producing more with the existing labour input or by producing the same output while saving labour. If the latter is the case, more labour can be allocated to other activities (Reardon et al., 1996). Household labour is also allocated to leisure[12] activities, besides income generating on- and off-farm activities.

Though it seems that technology adoption in agriculture is impeded by limited labour availability, this is rather caused by a lack of cash (Cramb et al., 1999; Moser and Barrett, 2003). In case a farm household faces scarcity of cash due to a failing capital market, labour becomes the scarcest input of all, as selling labour is the only means by which poor households can earn cash immediately. As a result, the opportunity cost of labour is high, causing a bottleneck for the adoption of labour-intensive technologies in agriculture, as household labour is allocated to off-farm activities (Janvry et al., 1991; Cramb et al., 1999). Thus, if terraces can increase farm labour productivity by saving labour input for cropping activities, farmers might be more willing to implement these practices.

8.1 Methodology

8.1.1 Theoretical background of production function

Econometric estimation of the production technology can be done through either the production function (primal or direct approach), or a profit or cost function (dual or indirect approach) (Mundlak, 2000; Zepeda, 2001). The production function describes the technological relation between combinations of inputs and outputs. The profit or cost function describes the producer's behaviour in choice of inputs, given the market prices (Sadoulet and Janvry, 1995).

Production function – a primal estimation

A production function is a purely physical concept, describing a relationship between inputs and output, in this case the agricultural production (Bairam, 1994; Upton, 1996):

$$Q = f(X) \qquad [8.1]$$

where Q is the output, and X is the vector of inputs. $f(\cdot)$ is the functional form of the production function defining the technical relationship between the inputs and output. It is assumed that the vector X consists of exogenous variables. If so, the function can be estimated with OLS regression techniques. However, under the assumption of profit maximisation, the explanatory variables might be endogenous, as the producer chooses the input quantities in order to obtain maximum profit. This implies that the error term is unknown to the observer but known to the producer himself (Mundlak, 2000; Coelli and Cuesta, 2001). This results in a simultaneous equations bias, as the error terms are correlated with the explanatory (endogenous) variables. However, in agriculture one can assume that the error term is partly known (management skills) and partly unknown (climate, pests) to the producer (Mundlak, 1996). Coelli and Cuesta (2001) show that if this is the case, OLS estimators are still the best choice despite the bias, especially if firms show a systematic non-profit maximising behaviour.

[12] In this case study, the term leisure comprises activities like religious duties, childcare, house repair, time spent on social relationships, etc. It thus includes all activities except the non-farm activities to earn cash income and the on-farm activities required to gain agricultural and animal products. These activities (or goods and services) are produced for direct use rather than for market exchange, and are referred to, as Z-goods in neoclassical literature (Ellis, 1988).

Profit function – a dual estimation

The dual approach is used as a solution for the possible endogeneity problem. The appearance of prices in the empirical equation distinguishes the dual approach from the primal. The basic idea of duality is that any point on the production function corresponds uniquely to a vector of price ratios and vice versa. As a result, variations in prices cause variations in quantities. Under duality, the technology is summarised by profit, cost, or revenue functions, referred to as dual functions. For competitive firms, prices, unlike quantities, are exogenous. Therefore, when prices are used as explanatory variables, these do not cause a simultaneous equations bias. Duality between technology and prices hold under well-defined conditions that can be tested empirically. In most studies these underlying conditions are not fully met; in particular, the concavity of the cost function or the convexity of the profit function is frequently violated (Mundlak, 2000). Moreover, problems might arise when some prices might be non-exogenous, when there is a lack of sufficient price variation, or when firms deviate from optimal (i.e. profit-maximising) behaviour (Coelli and Cuesta, 2001). These problems are very likely in case of subsistence farming, as the subsistence farm is not fully competitive and market prices cannot be applied for all inputs (e.g. labour).

As the farmers in the Peruvian Andes are only partly integrated into the markets, and agricultural production is mainly for subsistence purposes, it is expected that farmers do not show profit-maximising behaviour when it comes to agricultural production. Considering the arguments as briefly stated above, and the fact that the purpose of these analyses is to determine the impact of SWC practices on agricultural production – a technical relationship –, it was decided to use the primal approach by estimating production functions.

Selecting a functional form for the production function

There are different forms of production functions. Which one to choose depends on the nature of the producing unit that is estimated (Heady and Dillon, 1961). Determination of the true functional form of a given relationship is impossible, so the problem is to choose the best form for a given task, based on choice criteria (Griffin et al., 1987). These criteria can be hypotheses, data availability and properties, data-specific considerations and application-specific characteristics.

For the selection of the appropriate functional form for this case study, the following assumptions were made:

- When a farmer operates in uncertainty marginal productivities can be negative (Chambers, 1988; Hall, 1998). If the assumption of nonnegative marginal productivities is imposed by allowing only functions that never decrease, but in reality output decreases as input increases, the parameter estimates will be biased (Hall, 1998). However, in this case study the farming systems of subsistence farmers with limited access to inputs are analysed. It is thus assumed that these farmers did not yet reach the third stage of agricultural production, i.e. decreasing output when inputs are increased. Therefore, it can be assumed that the marginal productivities of the variable inputs are nonnegative.
- It is assumed that if all input variables are zero, the output is zero as well. However, if at least one of the input variable is positive, the output is also expected to be positive.
- The function is assumed to be concave.
- In order to simplify the computation (curvi-)linear functions are preferred, as these can easily be estimated with OLS regression techniques.

– The amount of parameters should be restricted in order to prevent multi-collinearity.

Based on Griffin et al. (1987), and considering the choice criteria as mentioned above, the Cobb-Douglas function was selected as being appropriate for this case study. The Cobb-Douglas production function is given by:

$$Q = Ax_1^{\alpha_1} x_2^{\alpha_2} \cdots x_n^{\alpha_n} \qquad [8.2]$$

where Q is the output, x_i is the input factor i, A is a constant, and α_i is the partial elasticity of production of y in relation to x_i. If $\sum \alpha_i$ is equal to 1 then there is a constant return to scale. The advantage of a Cobb-Douglas is the easy estimation by linear least squares.

Properties of the production function

The inputs used for production can be distinguished between fixed and variables inputs. Fixed inputs are resources that are constant in the short run. Variable inputs may increase or decrease, as production increases or decreases. On the long run all factors are variable, none is fixed.

Average and marginal product

Average product (AP) is the production per unit input factor and is often referred to as productivity (Katz and Rosen, 1998). The average product of the variable input is defined as (Colman and Young, 1989):

$$AP_{x_i} = \frac{Q}{X_i} \qquad [8.3]$$

The marginal product (MP) is the partial derivative of the production function over a production factor. In other words, it is the change in output resulting from a small change in the variable input expressed per unit of the input (Colman and Young, 1989):

$$MP_{x_i} = \frac{\partial Q}{\partial X_i} \qquad [8.4]$$

The marginal product of a Cobb-Douglas function is given by (Upton, 1996):

$$MP_i = \frac{dQ}{dX_i} = b_i c X_i^{(b_i - 1)} X_j^{b_j} = b_i \frac{Q}{X_i} \qquad [8.5]$$

The marginal product is thus equal to the coefficient multiplied with the average product. In general, the average product of a variable input diminishes along with the marginal product when inputs are increased.

Homogeneity and elasticity

The neo-classical production function is assumed to be homogeneous in order to meet the law of diminishing returns. This law implies that the additional amount of output gets smaller when the amount of input increases. This proportion is called the scale elasticity or scale of return. A homogeneous production function always yields a total scale elasticity ε, which is constant and equal to the degree of homogeneity υ. Total scale elasticity is the sum of the output elasticities ε_i, namely (Bairam, 1994):

$$\varepsilon = \sum \varepsilon_i = \sum \left(\frac{\partial Q}{\partial X_i} * \frac{X_i}{Q} \right) = \sum \frac{MP_i}{AP_i} \qquad [8.6]$$

where X_i is input i, and Q is the output. ε_i is the input elasticity or partial elasticity of production; i.e. the percentage change of output resulting from a percentage change in the variable input i. In a

Cobb-Douglas function, the estimated coefficient is the input elasticity. If the input elasticity is between 0 and 1, the law of diminishing marginal returns applies. If the elasticity is greater than 1 or smaller than 0, it would not be economically logic for the farmer to operate. The first because output grows more than proportionately with any increase in input which means the farmer could always gain more by using more of the input. And the second because output decreases as a consequence of using more of the input and the farmer clearly does better by reducing input use (Ellis, 1988). Similar, a function that is homogeneous of a degree greater than 1 has increasing returns to scale or economies of scale, and that is smaller than 1 has decreasing returns to scale or diseconomies of scale (Debertin, 1986).

Efficiency

When a farmer successfully maximises the output from given levels of input, he is technically efficient. A farmer is allocatively efficient when the production is efficient considering the relative prices of inputs and outputs. A factor of the production function is thus allocatively efficient if the slope of the production function, the marginal product (MP), is equal to the inverse ratio of input price (e.g. of labour) to output price (of the product) at the profit maximising point, that is when for example (Ellis, 1988):

$$MP_L = \frac{w}{p} \qquad [8.7]$$

where MP_L is the marginal product of labour, w is the wage rate and p is the price of the product.

However, in reality this widely accepted economic condition of profit maximisation is rarely observed. An empirical explanation is that the marginal cost of resource use includes the observed market cost plus some additional costs faced by producers. These additional or “shadow” costs have to be estimated (Lee and Zepeda, 2001). Mundlak (2000) subscribes the large spread of output and input compositions, or allocation errors, to incomplete information available to the econometrician about the behaviour of the firm. Dillon and Hardaker (1993) state that information from production function analysis can never be perfect because of uncertainty (climate, disease), imperfect data, unknown prices and opportunity costs, and differing observations, as each observation (farm) is unique, especially in resource qualities, preferences and management skills.

Important production factors

The following four factors are often mentioned as the main production factors in agricultural economics. These factors can substitute one and each other to a certain extent.

Land

Without land there is no agricultural production. Especially in subsistence farming the land area and the quality of the land that a farm household has at its disposal is critical since it determines the production potential (Beets, 1990). Land degradation is a serious threat to agriculture, as it deteriorates the soil quality and hence reduces land productivity (Semgalawe and Folmer, 2000). Land degradation results from intensification of agricultural land use without compensating investments in the maintenance of the soil (Coxhead and Shively, 1995). On mountain slopes, the main cause of land degradation is soil erosion. SWC practices are used to limit or prevent soil degradation due to erosion. The major benefits of SWC are: conserving water, retaining soil nutrients and organic matter, maintaining soil depth and soil structure (see Chapter 2 for further discussion). Hence, SWC technologies can maintain or improve the soil quality and thus land productivity or production potential.

Labour

Small-scale farming systems in LDCs are mainly based on family labour. Though family labour is normally unpaid, it has a subjective cost in terms of the leisure foregone. An individual will only work as long as the marginal product of the extra effort is valued higher than the foregone leisure. If opportunities for off-farm paid employment exist, labour employed on the farm has a direct opportunity costs measured by the off-farm wage which is foregone (Upton, 1996). Small-scale agriculture is often labour-intensive, as family labour is cheaper than machinery. When labour becomes scarce, it can be replaced by capital through mechanisation.

Capital

Capital not only includes money but everything used in production, which is not a gift of nature but has been produced in the past. Each item of capital controlled is known as an asset (Upton, 1996). If a farm household has access to capital (e.g. through credit), investments can be made in order to improve the other production factors and intensify the agricultural production. However, one of the characteristics of small-scale agriculture in LDCs is the limited access to capital.

Management skills

Empirical studies show a significant influence of management capacity on farm output. Management skills determine the quality of labour, and are thus another important production factor that should be incorporated into the production function. However, it is difficult to quantify the management capacity. It is most common to use personal aspects like education level, experience and/or age of the farmer as proxies for management capacity. Many studies found that these aspects have a positive influence on the farm results (Rougoor et al., 1998).

8.1.2 Material and methods

Sampling and data collection

In January and February 2002 a survey was carried out among 180 farm households in Pacucha and 192 farm households in Piuray-Ccorimarca. After testing the survey, local students with knowledge of agriculture and of the local language *Quechua* were attracted in order to carry out the survey. The survey forms were checked on a daily basis during the data collection period, in order to correct any mistakes or vagueness made by the interviewer. In the survey, cross-sectional data was collected on farm household characteristics, the farming system, characteristics of farmland, agricultural production of the year 2001, programme involvement, use of SWC practices, and the perceptions and opinions of the farm household. A few observations are left out of the analysis because of unreliable or incomplete data.

Variables used in production function

The production functions are estimated with OLS regression techniques. The agricultural production is represented by a Cobb-Douglas function, relating farm output to farm inputs and other factors affecting productivity. Cobb-Douglas functions were estimated for the gross output of agricultural production at household level, and for the main staple food crops.

The following formula is used:

$$\ln Q = \alpha_0 + \sum_i \alpha_i \ln X_i + \sum_j \beta_j F_j + \sum_k \gamma_k Z_k + u_i \qquad [8.8]$$

where α_0, α_i, β_i and γ_i are the coefficients, Q is the output, X_i are the inputs land, labour and fertilisers; F_j are the land characteristics of the farm; Z_k are the characteristics of the farm household k; and u_i is the error term with the expected value of zero and a normal distribution. Separate analyses are done for each watershed, since altitude, climate and market opportunities are different.

Independent variables that are not significant are omitted one by one after testing the null hypothesis that their coefficients equal zero with the F-test and likelihood ratio test. When this hypothesis is rejected, the variables are not omitted. In order to be able to compare the production functions, the same reduced set of variables is used for the different functions.

Dependent variables

The dependent variable in the production function is represented by Y. Cases with zero values for agricultural output were removed from the sample. The following variables are used as dependent variables (Table 8.1):

Table 8.1 *Description of dependent variables used in production functions*

Dependent variables		**Pacucha (N=176)**		**Piuray-Ccorimarca (N=188)**	
Variable	**Description**	**Mean**	***St.Dev.***	**Mean**	***St.Dev.***
Agricultural production	Monetary value (S/.) of farm household's agricultural production of the year 2001	1234	*1512*	1578	*2753*
Maize	Total maize production (kg) of household in year 2001	639	*800*		
Potato	Total potato production (kg) of household in year 2001			3215	*5674*

Table 8.2 *Description of independent variables of vector X used in production functions*

Independent variable		**Pacucha (N=176)**		**Piuray-Ccorimarca (N=188)**		
Variable	**Description**	**Mean**	***St.Dev.***	**Mean**	***St.Dev.***	
Crop area	Amount of hectares farmland cultivated in 2001	0.81	*1.11*	0.65	*1.17*	
Crop labour	Total amount of mandays applied to cropping activities (ploughing, sowing, weeding and harvesting) in year 2001	55.7	*54.6*	113	*204*	***
Dummy fertilisers	=1 if fertilisers are applied, 0 if not	0.87	*0.34*	0.98	*0.13*	***
Fertilisers	Total amount of fertilisers (kg) applied during year 2001	703	*1005*	2710	*5044*	**
% organic fertiliser	Percentage of fertilisers is organic fertilisers (kg/kg)	52	*48*	4	*19*	***
% chemical fertiliser	Percentage of fertilisers is chemical fertilisers (kg/kg)	2	*11*	15	*23*	
Dummy pesticides	=1 if pesticides are applied, 0 if not	0.091	*0.288*	0.170	*0.377*	***

Means of both watersheds are significant different at (*) 0.1 level, (**) 0.05 level, (***) 0.01 level

Farm inputs

The set of independent variables used in the production functions, are split up in three main factors: *X*, *F* and *Z*. The factor *X* represents the inputs for agricultural production (Table 8.2). Cases with zero values for land or labour input (i.e. missing values) were removed from the sample. For cases with zero values for fertiliser inputs, the natural log of fertiliser input was set at 0 (implying that the normal value was assumed to be 1). The dummies for fertiliser application were added to distinguish between cases with and without fertiliser input in order to avoid biased estimators (Battese, 1997).

Table 8.3 *Description of independent variables of vector F used in production functions*

Independent variable		Pacucha (N=176)		Piuray-Ccorimarca (N=188)		
Variable	**Description**	**Mean**	***St.Dev.***	**Mean**	***St.Dev.***	
Valley	% of total farmland located in valley	0.361	*0.357*	0.574	*0.373*	***
Rainfed	% of total farmland without access to irrigation	0.422	*0.348*	0.394	*0.401*	
Slope	Average class value (ranging from 1 -flat- till 3 -steep-) of soil depth for farmland	1.847	*0.603*	1.526	*0.513*	***
Soil fertility	Average class value (ranging from 1 -poor- till 3 -rich-) of soil fertility for farmland	1.830	*0.727*	1.846	*0.621*	
No stones	% of total farmland without stones	0.374	*0.361*	0.698	*0.351*	***
SWC	= 1 if farm household has implemented any SWC practices, 0 if not	0.591	*0.493*	0.596	*0.492*	
Bench terrace	= 1 if farm household has implemented bench terraces, 0 if not	0.545	*0.499*	0.160	*0.367*	***
Slow-forming terrace	= 1 if farm household has implemented slow-forming terraces, 0 if not	0.142	*0.350*	0.335	*0.473*	***
SWC years	Amount of years that farm households implements SWC practices	1.30	*1.43*	3.39	*3.85*	***
Tenure	% of total farmland with permanent user right	0.970	*0.126*	0.985	*0.072*	

Means of both watershed are significant different at (*) 0.1 level, (**) 0.05 level, (***) 0.01 level

Farmland characteristics

The vector *F* contains variables describing the quality of land (Table 8.3). The variables *slope*, *soil depth* and *soil fertility* have ordinal categories which are combined to one average value representing the farmland. The percentage of farmland belonging to a category is multiplied with the value of that category (with 3 is best, 1 is worst), and then the recalculated values for the three categories are summed up to one value, as is explained below:

- *Slope*: calculated value for the slope of farmland, which is the total sum of class values (3: steep, 2: gentle, 1: flat) multiplied with the percentage of farmland with corresponding class. Farm households are subdivided according to the steepness of their land: If the average value for slope of the farmland is equal or higher than 2, it is considered as gentle till steep; if it the value is lower than 2, it is considered as flat till gentle.
- *Soil depth*: calculated value for the soil depth of farmland, which is the total sum of class values (1: shallow, 2: regular, 3: deep) multiplied with percentage of farmland with corresponding class.

– *Soil fertility*: calculated value for the soil fertility of farmland, which is the total sum of class values (1: poor, 2: regular, 3: rich) multiplied with percentage of farmland with corresponding class.

Farm household characteristics

The vector *Z* represents the variables describing the farm household (Table 8.4). A few variables mentioned in the table are further explained below:

– *Education*: Education level of head of farm household. *Education* = 1 if no education; = 2 if primary school unfinished; = 3 if primary school finished; = 4 if secondary school unfinished; = 5 if secondary school finished; = 6 if higher education; = 7 if professional training.
– *Risk taker*: Head of farm household is risk taker; the head was asked to give his preference between two different deals: a risky deal with a chance of high profit or loss, or a deal with moderate profit for sure. Expected profit of the two deals was the same. *Risk taker* = 1 if head of household choose risky deal; 0 otherwise.
– *Long-term*: Head of farm household has long-term perspective; head of household was asked to give his preference between two deals: more money on long-term, or less money on short-term. *Long-term* = 1 if head of household choose for long-term deal; 0 otherwise.

Table 8.4 *Description of independent variables of vector Z used in production functions*

Independent variables		**Pacucha (N=176)**		**Piuray-Ccorimarca (N=188)**		
Variable	**Description**	**Mean**	***St.dev.***	**Mean**	***St.dev.***	
Family size	Total amount of farm household members	5.108	*1.987*	4.745	*1.890*	*
Gender	= 1 if gender of head of household is male, 0 if female	0.835	*0.372*	0.957	*0.202*	***
Age	Age of head of household	39.8	*13.0*	40.0	*12.6*	
Education	Ranking of education level of head of household	2.66	*1.26*	3.24	*1.33*	***
Dependency ratio	Number of household members younger than 16, divided by total number of household members	0.459	*0.223*	0.454	*0.217*	
Risk taker	= 1 if head of household is risk taker, 0 otherwise	0.489	*0.501*	0.596	*0.492*	**
Long-term	= 1 if head of household chooses for long-term case, 0 otherwise	0.494	*0.501*	0.638	*0.482*	***
Livestock	Monetary value (S/.) of livestock owned by farm household	2523	*1901*	2417	*1585*	
Off-farm income	Total amount of off-farm income (S/.) that farm household earned during year 2001	1943	*2084*	3969	*5426*	***
Presence	Number of months that head of household is present on farm during year 2001	11.7	*1.098*	11.7	*1.064*	
Incentives money	Total amount of money (S/.) farm household received for implementation of SWC practices	51.6	*108.6*	10.2	*40.8*	***
Incentives tools	Total value of tools (S/.) farm household received for implementation of SWC practices	14.3	*45.5*	42.6	*71.1*	***
Ayni	= 1 if farm household makes use of reciprocal labour exchange for agricultural activities	0.94	*0.25*	0.97	*0.18*	
Contract labour	= 1 if farm households makes use of contracted labour for agricultural activities	0.61	*0.49*	0.45	*0.50*	***

Means of both watershed are significant different at (*) 0.1 level, (**) 0.05 level, (***) 0.01 level

Selectivity bias correction

Introducing the dummy for SWC adoption might cause a selectivity bias in the production function, as the farm households who decided to adopt SWC practices might be significantly different from the farm households who did not adopt SWC practices. These significant differences among the two groups might cause difference in the farm output. Therefore, to prevent biased results, a correction term has to be introduced in the production function. Inverse Mill's Ratios are used to correct for any selectivity bias in the production function, as was done in the adoption analyses (see Chapter 7 for further explanation). This results in the following correction terms (Blundell and Costa-Dias, 2000):

$$Y_i = \beta + d_i \left[\alpha_T + \rho_{(\varepsilon,\upsilon)} \frac{\phi(Z_i \hat{\gamma})}{\Phi(Z_i \hat{\gamma})} \right] + (1 - d_i) \rho_{(\varepsilon,\nu)} \frac{-\phi(Z_i \hat{\gamma})}{1 - \Phi(Z_i \hat{\gamma})} + \mu_i \qquad [8.9]$$

where Y_i is the output of farm i, β is the vector of all explanatory variables, and d_i is a dummy representing SWC adoption. In case the correction terms are not significant, they are tested with the F-statistic and likelihood ratio statistic whether they can be omitted (Pindyck and Rubinfeld, 1998).

8.2 The effect of terraces on agricultural production in the Andes

8.2.1 Agricultural production at household level in Pacucha

Production functions

The main determinants of the agricultural production are labour, land and fertilisers (Table 8.5).

Table 8.5 *Production functions agricultural production Pacucha*

Sub-sample	All	No terraces	Terraces
N	176	79	97
Independent variables	**β**	**β**	**β**
Constant	2.447***	1.581	3.524***
LN(crop area)	0.289***	0.350**	0.169
LN(crop labour)	0.415***	0.512**	0.369***
LN(fertiliser)	0.220***	0.266**	0.205**
Dummy fertiliser	-0.937**	-1.361**	-0.835
% chemical fertiliser	0.374	0.016	0.542
Dummy pesticide	-0.411*	-0.468	-0.352
Slope	-0.474***	-0.536***	-0.384**
Soil fertility	0.174*	0.208	0.146
Dummy bench terrace	0.148	(dropped)	0.436*
Dummy slow-forming terrace	0.105	(dropped)	0.167
SWC years	0.108*	0.223	0.152**
Dependency ratio	-0.441	-0.012	-0.673*
Risk taker	0.058	0.077	0.056
Livestock	-3.9E-5	-4.9E-5	-2.7E-5
Ayni	0.406	0.474	0.093
Adjusted R^2	0.717	0.755	0.506
Prob. (F-statistic)	0.000	0.000	0.000

** significant at 0.05 level, ** significant at 0.01 level, *** significant at 0.001 level*

Slope is negatively influencing the production. The steep slopes are located at higher altitudes and often imply shallow and poor soils, that is, these are the marginal areas for agricultural production.

Bench terraces are the only SWC practices that significantly induce a production increase. Bench terraces are also the major SWC practice that is implemented in this watershed. The amount of years that the household implements SWC practices also positively influences the production. For practices like bench terraces, the positive influence on production is noticeable after a few years, as soil improvement is not immediate. Household characteristics like education, age and gender of head of household, are not significant, indicating that management skills do not have a large influence. The dependency ratio negatively influences the agricultural production for the sub-sample of observations with terraces. This implies that farm households with a larger ratio of children under age of 16 produce less. The production functions with the complete list of variables can be found in Appendix 8.1.

Maize is the main crop cultivated in Pacucha. Table 8.6 shows the results of the estimated production function for maize. Labour is the most important variable factor for maize production. Land and fertilisers are less significant. Soil fertility positively influences maize production, but the slope is not significant any more. As maize is mainly cultivated in the valley bottoms, the slope is flat till gentle in most cases, explaining the insignificance of slope. The dependency ratio is negative for maize production. Farm households willing to take risk produce more maize. Bench terraces as well as the years of SWC implementation positively influence the maize production.

Table 8.6 *Production functions maize production Pacucha*

Sub-sample	All	No terraces	Terraces
N	149	92	57
Independent variables	**β**	**β**	**β**
Constant	1.770**	1.061	2.960**
LN(crop area)	0.332***	0.439***	0.120
LN(crop labour)	0.411***	0.336**	0.581**
LN(fertiliser)	0.134**	0.131	0.134
Dummy fertiliser	-0.617	-0.771	-0.384
Rainfed	-0.277	-0.448	0.143
Slope	-0.164	-0.218	-0.058
Soil fertility	0.150*	0.221*	0.061
Bench terrace	0.072	(dropped)	0.033
Slow-forming terrace	-0.261	(dropped)	-0.329
SWC years	0.122**	0.074	0.172**
Dependency ratio	-0.642**	-0.450	-0.903**
Risk taker	0.321**	0.334*	0.289
Ayni	0.275	0.413	0.101
Adjusted R^2	0.661	0.668	0.584
Prob. (F-statistic)	0.000	0.000	0.000

** significant at 0.05 level, ** significant at 0.01 level, *** significant at 0.001 level*

Productivity and efficiency

With the results of the production functions, the productivity and marginal products of land, labour and fertiliser are calculated for the total agricultural production (Table 8.7) and for maize production (Table 8.8). The values were re-estimated for sub-samples of farms with and without terraces and farms with flat till gentle slopes or gentle and steep slopes.

The output (agricultural production) was higher on farms with terraces than farms without. Only on farms with gentle and steep slopes, this difference in agricultural production was significant. For farms with gentle and steep slopes, the output and the inputs of labour, land and fertilisers are significantly higher on farms with terraces than on those without. This indicates that terraces successfully enable agricultural production on sloping land. On the gentle and steep slopes, terraces increase the productivity and marginal products of the three variable inputs land, labour and fertilisers. However, this difference was only significant for labour productivity. The number of farm households applying fertilisers (n_i / N) is significantly more on farms with SWC. MARENASS introduced terraces together with compost techniques. Most farmers therefore apply terraces together with organic fertilisers. Also the chemical fertilisers are applied more frequently on farms with terraces. The results indicate an increased productivity of fertilisers due to terraces on gentle and steep slopes, but the increase is not significant.

The marginal product indicates the technical efficiency of a farm: the higher the value (i.e. the steeper the slope of the production function), the more technically efficient the farmer operates. Only at gentle and steep slopes, terraces result in an increased technical efficiency of land. The MP of labour is increased due to terraces, as well as the marginal product of fertilisers. Labour and fertilisers are thus more efficiently used on farms with terraces than on farms without terraces.

The labour allocation of a farm household on agricultural production is efficient, if the marginal product of labour equals the market wage (that is, S/. 10). On average, the marginal product of labour is indeed equal to the market wage. On farms with flat till gentle slopes, the marginal product of labour is higher, but on farms with gentle and steep slopes, the marginal product of labour is lower except for farms with terraces.

Table 8.7 *Variable factor productivity of total agricultural production (S/.), Pacucha*

					Slope: flat till gentle				**Slope: gentle and steep**			
	All	**No terraces**	**Terraces**		**All**	**No terraces**	**Terraces**		**All**	**No terraces**	**Terraces**	
N	176	79	97		91	48	43		85	31	54	
Output	1234	991	1433		1623	1448	1818		818	282	1126	***
Land productivity (S/. ha^{-1})												
Input	0.81	0.59	0.99		0.89	0.69	1.11		0.72	0.43	0.89	*
AP	2156	2001	2282		2630	2586	2679		1649	1095	1966	
MP	622	701	385		639	695	258		418	187	371	
ε	0.289	0.350	0.169		0.243	(0.269)	(0.096)		0.254	(0.171)	(0.189)	
Labour productivity (S/. manday^{-1})												
Input	55.7	39.5	69.0	**	60.8	52.3	70.3	*	50.3	19.7	67.9	**
AP	24.0	22.2	25.5		26.4	26.6	26.3		21.4	15.3	24.9	*
MP	10.0	11.3	9.4		10.8	13.3	15.2		8.5	6.0	9.5	
ε	0.415	0.512	0.369		0.410	0.499	(0.580)		0.397	(0.390)	0.383	
Fertiliser productivity (S/. kg^{-1})												
n_i / N	*0.87*	*0.76*	*0.96*	***	*0.87*	*0.81*	*0.93*		*0.87*	*0.68*	*0.98*	**
AP	3.67	3.02	4.08		3.80	3.28	4.31		3.52	2.54	3.91	
MP	0.806	0.804	0.837		1.507	1.497	1.653		0.372	0.435	0.487	
ε	0.220	0.266	0.205		0.396	(0.456)	0.383		0.106	(0.171)	(0.125)	

AP is significant different between farms with and without terraces at (*) 0.05, (**) 0.01 or (***) 0.001 level. Values for ε between brackets were not significant. In these cases, the ε and the MP can be considered 0.

Considering only maize production (Table 8.8), land productivity is higher on farms with terraces, but its marginal product is lower. In case of gentle and steep slopes the marginal product is even negative. This is due to a negative coefficient for land in the estimated production function. However, this coefficient was not significant and can thus be considered zero. Labour productivity is higher for farms with terraces on gentle and steep slopes. On flat till gentle slopes the labour productivity is slightly less due to terraces. The marginal product and elasticities of labour are higher for farms with terraces in all cases. In case of farms with gentle and steep slopes, and with terraces, the marginal product of labour is higher than the average product. This implies that, by adding one day of labour, the productivity of labour can still be increased. Instead, less labour is invested in maize production on farms with terraces on gentle and steep slopes, than on farms without terraces on gentle and steep slopes. In this case, farmers with terraces do not operate efficiently from a technical point of view. Fertiliser productivity is lower on farms with terraces than on farms without terraces. This is in contrast with the increased frequency of fertiliser application on farms with terraces. However, as was shown in Chapter 5, the fertilisers used for maize production are applied on the less fertile soils, disguising the effect of fertilisers in a with – without comparison.

Table 8.8 *Variable factor productivity of maize production (kg), Pacucha*

					Slope: flat till gentle			**Slope: gentle and steep**			
	All	**No terraces**	**Terraces**		**All**	**No terraces**	**Terraces**	**All**	**No terraces**	**Terraces**	
N	149	92	57		89	58	31	60	34	26	
Output	751	749	754		915	949	850	509	408	640	
Land productivity (kg ha^{-1})											
Input	0.48	0.48	0.47		0.50	0.51	0.48	0.46	0.46	0.45	
AP	1890	1801	2035		2066	1995	2198	1630	1470	1840	
MP	627	791	244		885	1151	745	318	507	-419	
ε	0.332	0.439	(0.120)		0.428	0.577	(0.339)	(0.195)	0.345	(-0.228)	
Labour productivity (kg manday^{-1})											
Input	29.3	29.5	28.8		35.4	35.4	35.3	27.8	32.8	21.2	*
AP	27.1	26.5	28.0		26.3	26.7	25.6	28.3	26.2	30.9	
MP	11	9	16		11	*8*	*12*	10	*5*	37	
ε	0.411	0.336	0.581		0.425	(0.296)	(0.463)	0.369	(0.182)	1.189	
Fertiliser productivity (kg kg^{-1})											
n_i / N	*0.87*	*0.83*	*0.95*	*	*0.85*	*0.83*	*0.90*	*0.90*	*0.82*	*1.00*	*
AP	4.82	6.09	3.02		5.76	7.48	2.81	3.49	3.71	3.25	
MP	0.65	0.80	0.40		0.77	0.68	0.40	0.52	0.89	0.33	
ε	0.134	(0.131)	(0.134)		0.134	(0.091)	(0.141)	0.148	0.240	(0.101)	

AP is significant different between farms with and without SWC at (*) 0.05 level.
Values for ε between brackets were not significant. In these cases, the ε and the MP can be considered 0.

The production is allocative efficient if the marginal product equals the ratio of the input price to the output price. Considering the labour input, the market wage for labour is S/.10 per manday. Maize values about S/.1.05 per kg on the market, thus the price ratio is equal to 9.52. Considering only maize production (Table 8.8), the marginal product for labour on farms with SWC is higher than this ratio, implying that the profit for on-farm labour is higher than the market wage. For farms without terraces, the MP of labour is about this ratio or lower in case of gentle and steep slopes. A farm household is only economically efficient if it operates both technically and allocatively efficient (Ellis, 1988), which is not the case here.

8.2.2 Agricultural production at household level in Piuray-Ccorimarca

Production functions

Table 8.9 contains the results of the estimated production functions for agricultural production in Piuray-Ccorimarca. Land, labour and fertilisers are important determinants for agricultural production. Slope is negatively influencing the agricultural production, except for farms with terraces.

Table 8.9 *Production functions agricultural production, Piuray-Ccorimarca*

Sub-sample	All	No terraces	Terraces
N	188	81	107
Independent variables	**β**	**β**	**β**
Constant	1.994**	2.308	1.826*
LN(crop area)	0.275***	0.199	0.317***
LN(crop labour)	0.395***	0.642***	0.279**
LN(fertiliser)	0.213**	-0.058	0.321***
Dummy fertiliser	-1.047	0.736	-1.429
% chemical fertiliser	0.423	-0.311	0.947*
Dummy pesticide	-0.134	-0.021	-0.086
Slope	-0.232*	-0.618**	-0.049
Soil fertility	0.131	0.132	0.077
Bench terrace	0.085	(dropped)	0.053
Slow-forming terrace	0.167	(dropped)	0.156
SWC years	-0.008	0.029	-0.026
Dependency ratio	-0.069	0.020	-0.203
Risk taker	-0.014	-0.069	-0.032
Livestock	6.3E-5	1.8E-4**	7.9E-6
Ayni	0.301	(dropped)	0.296
Adjusted R^2	0.572	0.520	0.647
Prob. (F-statistic)	0.000	0.000	0.000

** significant at 0.05 level,** significant at 0.01 level, *** significant at 0.001 level*

The positive influence of fertilisers on production is more pronounced for farms with terraces. Also the percentage of chemical fertilisers applied is significant for these farms. The most common SWC practice in Piuray-Ccorimarca is the slow-forming terrace. However, this variable is not significant in the production function. The effect of slow-forming terraces on production is assumed to be less than bench terraces. The production functions with the complete list of variables can be found in Appendix 8.2.

The main food crop in Piuray-Ccorimarca is potato. The results of the estimated production function for potato can be found in Table 8.10. The production functions are quite similar to those for the total agricultural production (Table 8.9). Permanent tenure rights positively influence the potato production. In case of farms without terraces, the slope negatively influences the potato production. The amount of years that the farm households implements SWC practices, is negatively determining the potato production. This suggests that the SWC practices deteriorate over the years due to bad maintenance. Household characteristics and field characteristics have no significant influence on the potato production.

Table 8.10 *Production functions potato production, Piuray-Ccorimarca*

Sub-sample	All	No terraces	Terraces
N	180	95	85
Independent variables	**β**	**β**	**β**
Constant	2.717**	2.302	2.561*
LN(crop area)	0.336***	0.220*	0.473***
LN(crop labour)	0.345***	0.546***	0.175
LN(fertiliser)	0.301***	0.228*	0.288***
Dummy fertiliser	-2.324***	-1.665	-2.430**
% chemical fertiliser	0.695*	0.472	0.966*
Dummy pesticide	-0.222	-0.194	-0.111
Permanent	1.208*	1.642	0.958
Slope	-0.162	-0.466*	0.079
Soil fertility	0.016	0.121	-0.017
Rainfed	0.145	0.136	0.256
Bench terrace	0.174	(dropped)	0.282
Slow-forming terrace	0.117	(dropped)	0.306
SWC years	-0.015	0.010	-0.051*
Dependency ratio	-0.088	0.260	-0.498
Risk taker	-0.053	-0.016	-0.020
Adjusted R^2	0.644	0.588	0.729
Prob. (F-statistic)	0.000	0.000	0.000

** significant at 0.05 level,** significant at 0.01 level, *** significant at 0.001 level*

Productivity and efficiency

Results in Table 8.11 show that the agricultural output is higher on farms with terraces than farms without terraces. This difference is more pronounced on gentle and steep slopes. However, the land productivity is lower, except on the gentle and steep slopes. The marginal product of land, on the other hand, is higher on farms with terraces, indicating that land is used more technically efficient.

Labour productivity is higher for farms with terraces on gentle and steep slopes, but not on flat till gentle slopes. The marginal product and elasticities of labour are lower in all cases. Fertiliser productivity is slightly lower on farms with terraces. None of the elasticities for fertilisers in the production functions were significant. Note that the differences in output and productivity between farms with terraces and farms without terraces are insignificant. The marginal product of labour is lower than the market wage, suggesting that labour is not efficiently allocated to agricultural production.

Considering only the potato production (Table 8.12), the output is higher on farms with terraces than on farms without terraces. The land productivity of farms with terraces is lower, but its marginal product higher. The marginal product of labour, on the other hand, is lower on farms with terraces than on farms without terraces. The labour productivity is increased by terraces on farms with gentle and steep slopes, but decreased on farms with flat till gentle slopes. The differences for fertiliser productivity are not very pronounced. Again, the differences in output and productivity between farms with and without terraces are insignificant.

Table 8.11 *Variable factor productivity of total agricultural production (S/.), Piuray-Ccorimarca*

				Slope: flat till gentle			Slope: gentle and steep		
	All	No terraces	Terraces	All	No terraces	Terraces	All	No terraces	Terraces
N	188	81	107	134	58	76	54	23	31
Output	1578	1455	1672	1458	1406	1497	1878	1577	2102
Land productivity (S/. ha^{-1})									
Input	0.65	0.55	0.72	0.57	0.58	0.57	0.83	0.49	1.08
AP	4685	5015	4435	4750	5319	4316	4525	4249	4729
MP	1289	996	1407	1269	1200	1438	1001	35	1277
ε	0.275	(0.199)	0.317	0.267	0.226	0.333	(0.221)	(0.008)	0.270
Labour productivity (S/. mandays^{-1})									
Input	113.2	93.4	128.2	100.7	95.1	105.0	144.1	89.1	184.9
AP	17.0	16.3	17.4	17.3	18.2	16.7	16.1	11.6	19.4
MP	6.7	10.5	4.9	6.3	9.1	3.5	6.3	12.0	5.3
ε	0.395	0.642	0.279	0.361	0.499	0.212	0.394	1.036	(0.274)
Fertiliser productivity									
n_i / N	*0.98*	*0.99*	*0.98*	*0.99*	*0.98*	*0.99*	*0.98*	*1.00*	*0.97*
AP	1.47	1.54	1.42	1.70	1.75	1.67	0.88	1.01	0.78
MP	0.31	-0.09	0.45	0.49	0.29	0.63	0.07	-0.49	0.20
ε	(0.213)	(-0.058)	(0.321)	(0.289)	(0.165)	(0.378)	(0.083)	(-0.481)	(0.261)

Values for ε between brackets were not significant. In these cases, the ε and the MP can be considered 0.

Table 8.12 *Variable factor productivity of potato production (kg), Piuray-Ccorimarca*

				Slope: flat till gentle			Slope: gentle and steep		
	All	no SWC	SWC	All	no SWC	SWC	All	no SWC	SWC
N	180	95	85	125	71	54	55	24	31
Output	3361	2808	3978	3024	2676	3481	4126	3199	4843
Land productivity (kg ha^{-1})									
Input	0.48	0.41	0.55	0.42	0.42	0.42	0.60	0.37	0.77
AP	11817	13009	10485	12106	13569	10181	11162	11351	11015
MP	3971	2861	4963	3988	3022	5474	2714	850	3933
ε	0.336	0.220	0.473	0.329	0.223	0.538	(0.243)	(0.075)	0.357
Labour productivity (kg mandays^{-1})									
Input	95.1	66.5	105.8	72.4	64.8	82.4	113.9	71.7	146.5
AP	48.7	48.2	49.3	50.2	53.7	45.6	45.4	32.2	55.7
MP	16.8	26.4	8.6	17.7	25.9	14.7	17.8	24.2	6.3
ε	0.345	0.546	0.175	0.352	0.483	0.323	0.391	(0.750)	(0.112)
Fertiliser productivity									
n_i / N	*0.99*	*0.99*	*0.99*	*0.98*	*0.99*	*0.98*	*1.00*	*1.00*	*1.00*
AP	3.28	3.31	3.24	3.65	3.47	3.89	2.43	2.83	2.12
MP	0.99	0.76	0.93	1.05	0.92	0.93	0.58	1.08	0.52
ε	0.301	0.228	0.288	0.286	0.266	0.240	(0.237)	(0.380)	0.243

Values for ε between brackets were not significant. In these cases, the ε and the MP can be considered 0.

The production is allocatively efficient if the marginal product equals the ratio of the input price to the output price. Taking the average market prices for labour, a wage is S/.10 per manday and potato values S/.0.39 per kg. The price ratio is thus equal to 25.6. The marginal product values of labour for potato production for farms without terraces are about this value. The marginal products for farms with terraces are lower than this ratio, implying that the value of farm labour is less than the market wage. As the terraces are installed on marginal land, marginal productivity is to be expected less. Farms without terraces are located at the fertile valley bottom, and thus produce more. Another explanation might be found in the main SWC practice: slow-forming terraces. Its effect on production is less than bench terraces.

8.2.3 Factor scarcity and access to markets in Pacucha and Piuray-Ccorimarca

In Table 8.13 an overview is given of the average values of the production factors for the two research areas Pacucha and Piuray-Ccorimarca. The value of the output (crop yield) is slightly more in Piuray-Ccorimarca than in Pacucha, though this difference is not significant. However, in Piuray-Ccorimarca farm households sell a significantly larger part of their production on the market than the farm households in Pacucha. Farm households in Pacucha own more land than in Piuray-Ccorimarca. However, the amount of hectares cultivated in the year 2001, was not significantly different. Land productivity is significantly higher in Piuray-Ccorimarca than in Pacucha. The farmers were asked how much they were willing to pay if they had to hire their own land for one year[13]. The farmers in Piuray-Ccorimarca valued their land much higher than in Pacucha. This suggests that land is scarcer in Piuray-Ccorimarca than in Pacucha.

In Pacucha, farmers complained significantly more often about labour shortage during peak periods in agriculture, than the farmers in Piuray-Ccorimarca. Farmers in Pacucha also hired more labour for agricultural activities. Time spent on farm activities is equal in both areas, but the labour spent on cropping activities is lower in Pacucha, resulting in a higher crop labour productivity. Cultivation in Piuray-Ccorimarca is more labour intensive than in Pacucha, as potato requires more labour than maize. Off-farm labour productivity, however, is twice as much in Piuray-Ccorimarca than in Pacucha. Farmers in Piuray-Ccorimarca are better educated than those in Pacucha, but this only partly explains the difference in off-farm wage. Farmers in Piuray-Ccorimarca also have a better access to the labour market than in Pacucha. That is, in Piuray-Ccorimarca there are more opportunities for off-farm labour, as it is situated close to the large city Cusco, and infrastructure is better than in Pacucha. Many derive income from relatively lucrative jobs like taxi driver, a porter for tourists or making and selling crafts, besides wage labourer. In Pacucha, the opportunities for off-farm labour are limited to wage labourer at other farmers' fields or in construction work. Though the head of the farm household spends similar amount of time on farm-, off-farm, and leisure[14] activities in both areas, the other household members have more time for leisure activities

[13] Since the land belongs to the community, farmers cannot sell their land. Many farmers could thus not mention an amount for how much they were willing to buy their own land. However, they do have the custom to rent their land to others. Therefore, during the survey they were asked how much they were willing to pay to hire their own land for one year, in order to have an indication of how much farmers value their land.

[14] Leisure is measured, as the amount of days that is left, after distracting the days spent on farm and off-farm activities from 365. Children below 6 were assumed not to contribute to the household labour, children between 6 and 12 were assumed to contribute the equivalent of a quarter of an adult, children between 12 and 16 the equivalent of half an adult.

in Pacucha than in Piuray-Ccorimarca. These data suggest that, instead of labour being scarcer in Pacucha, there are rather more failures in the labour market.

Table 8.13 *Availability of production factors in Pacucha and Piuray-Ccorimarca*

	Pacucha			Piuray-Ccorimarca			
Output	**Average**	**St.dev.**	**N**	**Average**	**St.dev.**	**N**	
Value agricultural production (S/. y^{-1})	1234	1512	176	1578	2753	188	
Part of production sold on market (%)	13.6	21.0	176	31.5	23.1	188	***
Production factors							
Land							
Total farm area (ha)	1.066	1.409	176	0.728	1.166	188	*
Cultivated area (ha)	0.810	1.111	176	0.646	1.168	188	
Population density (person ha^{-1})	14.6	19.9	176	25.8	32.3	188	***
Land productivity (S/. ha^{-1})	2156	2072	176	4685	4999	188	***
Willingness to hire (S/. ha^{-1})	538	671	115	2585	3082	120	***
Labour							
Contracted labour (dummy)	0.608	0.490	176	0.447	0.498	188	**
Labour shortage (dummy)	0.898	0.305	176	0.814	0.390	188	*
Farm labour (mandays y^{-1})	581	292	176	586	334	188	
Crop labour (mandays y^{-1})	56	55	176	113	204	188	***
Crop labour (mandays y^{-1} ha^{-1})	108	105	176	488	1172	188	***
Value crop labour (S/. $manday^{-1}$)	24.0	19.1	176	17.0	17.5	188	***
Non-farm labour (mandays y^{-1})	167	131	176	174	139	188	
Value non-farm labour (S/. $manday^{-1}$)	10.1	10.0	176	20.7	23.9	188	***
Leisure household (mandays y^{-1})	433	359	176	354	267	188	*
Leisure head of household (mandays y^{-1})	70.8	68.8	176	80.8	49.9	188	
Fertilisers							
Organic fertilisers (dummy)	0.858	0.350	176	0.931	0.254	188	*
Organic fertilisers (kg)	809	1037	151	2639	4628	175	***
Chemical fertilisers (dummy)	0.136	0.344	176	0.878	0.329	188	***
Chemical fertilisers (kg)	61.7	74.6	24	289	677	165	
Purchased inputs (dummy)	0.619	0.487	176	0.803	0.399	188	***
Value purchased inputs (S/.)	46.8	67.1	109	136	239	151	***
Value agric.prod. / value purchased inputs	88.5	159.1	109	34.2	68.2	151	***

The average values are significant different between households in Pacucha and Piuray-Ccorimarca at 0.05 (*) level, at 0.01 level (**) or at 0.001 level (***).

In Piuray-Ccorimarca, more fertilisers are applied than in Pacucha. As farmers in Piuray-Ccorimarca spend more capital on purchased inputs (like chemical fertilisers and pesticides), the productivity of these inputs is lower. Potatoes require more fertilisers and pesticides than maize, but also more capital is available in Piuray-Ccorimarca than in Pacucha.

Considering the three input factors (land, labour and fertilisers), it seems that agriculture in Piuray-Ccorimarca is more intensive than in Pacucha. In Piuray-Ccorimarca, land is scarcer, more capital is available due to off-farm opportunities, and the crop potato requires more input (labour and fertilisers) than maize. In Pacucha, on the other hand, the labour market is more restricted. Though the farm labour productivity is high, farmers cannot convert this into cash, as the market for agricultural products is also limited. The farming system in Pacucha is characterised by low-external input agriculture (LEIA), implying that available resources are used and different farm activities are combined to create synergistic effects. The farming system in Piuray-Ccorimarca is characterised by high-external input agriculture (HEIA), which means that it is focused on capital intensification through improvement of land and labour productivity, and agriculture is commercially oriented (Ruben et al., 1996).

8.3 Terraces, productivity and markets

The estimated production functions showed that in both regions the most common determinants of agricultural production are land, labour, fertilisers and the slope of the farmland. The production functions were re-estimated for farms without and with terraces. In all cases, the coefficient of the slope was smaller for farms with terraces than for those without, indicating that terraces help to reduce the negative impact of the slope on production. Terraces enable agricultural production on sloping land.

Average products and marginal products were calculated in order to define the impact of terraces on the three factors land, labour and fertilisers. The effects of terraces on output and productivity are more pronounced on farms with gentle and steep sloping land in both areas. In Pacucha, the productivity (i.e. average product) of the inputs land and labour are increased due to terracing. In Piuray-Ccorimarca, this positive effect of terraces on productivity is only achieved on the gentle and steep slopes. The effect of terraces on fertiliser productivity is less clear, though the marginal product of fertilisers was higher on farms with terraces indicating an increased efficiency. Fertilisers are also more frequently applied on farms with terraces than on farms without terraces. In Piuray-Ccorimarca, none of the differences in productivity between farms with and without terraces are significant. This implies that in Piuray-Ccorimarca the terraces do not affect productivity in agriculture. One reason might be that the main SWC practices in Piuray-Ccorimarca are the slow-forming terraces. The effect of this practice on production is limited, and only noticeable on the long-term (Rist and Martin, 1991). Another reason can be that most terraces are installed on marginal land with a lower production potential. In Pacucha, terraces significantly increase the output and labour productivity on farms with gentle and steep slopes. Here, the main SWC practices are bench terraces, which have a more pronounced effect on production. It should be noted that in Pacucha mainly manual labour was used. Bench terraces facilitate manual labour in cropping activities (e.g.: tillage, weeding, harvest) because of the levelling of the slope. Other examples in the Andes have shown that terraces make mechanised tillage (with oxen plough or tractor) more difficult if not impossible (e.g.: Winters et al., 2004). In these cases, labour productivity decreases, and for that reason terraces are sometimes removed.

In Pacucha, the marginal product of land is lower on farms with terraces (except for gentle and steep slopes) and the marginal product of labour is higher. The use of land is thus less technically efficient, and the use of labour more technically efficient for agricultural production on terraces. In Piuray-Ccorimarca, it is exactly the opposite: the marginal product of land is higher on farms with terraces, whereas the marginal product of labour is lower than on farms without terraces. To be able to explain these opposite effects of terraces on labour and land in the two regions, one has to consider factor scarcity and factor markets. In Piuray-Ccorimarca, land is scarcer but more capital is available than in Pacucha, resulting in a more intensive (i.e. HEIA) farming system. Terraces have potential to contribute to this intensification of agriculture. LEIA farming systems, like in Pacucha, are restriced to environments with low market development (Ruben et al., 1996).

At first hand, labour seems to be scarcer in Pacucha than in Piuray-Ccorimarca. However, a closer look at the data on off-farm labour indicates that in Pacucha there is a more restricted labour market than in Piuray-Ccorimarca. Though the labour allocation between farm, off-farm and leisure activities of the heads of the farm households are equal in the two regions, the other household members spend more time on leisure activities in Pacucha. Off-farm labour productivity is lower in Pacucha than in Piuray-Ccorimarca, but the crop labour productivity is larger as the crop labour input is lower. In Pacucha, the labour productivity increases as well as the marginal product of labour due to terracing. Also the labour input in agricultural production increases, but this is not allocated to the production of the main food crop: maize. It appears that farmers with terraces invest less labour in maize production. With an imperfect off-farm labour market, one would expect that farmers allocate more labour to food crops. However, there is also a missing output market in Pacucha. As farmers explained themselves, there is no use in producing more maize if you cannot eat it nor sell it. Instead, they decide to produce the same output, while saving labour allocated to maize production. This also explains the remarkable result of the marginal product of labour that was larger than the average product. A farmer would be more efficient by adding more labour. Though the labour productivity would then still increase, this is of no use to the farmer as he cannot eat the extra maize produced. One should note that the maize variety (morocho) cultivated on the slopes is mainly used for home consumption, whereas the maize variety (almidon) in the valley is more often sold on the market. Thus, as long as farmers cannot utilise the increased crop labour productivity due to terraces for their livelihood, there is no incentive to invest more in terracing.

If access to the off-farm labour market in Pacucha would be improved, farmers can convert their labour into cash. Off-farm labour productivity will rise, and as a consequence, crop labour productivity is expected to rise as well. Terraces significantly increase crop labour productivity on sloping land. However, instead of investing in terracing, farmers will probably move to the valley for crop production, as the crop labour productivity is the highest at flat till gentle slopes. If the access to the output market is improved, and there is no change in the existing labour market, farmers will be more willing to invest in terraces, as they will be able to convert their crop labour productivity into cash. The decision of a farm household to invest in terracing thus relates both to the assets available (labour, cash) and the attractiveness of agricultural intensification as a livelihood strategy. It is shown in several studies that if households depend on crop production for their livelihoods, they invest more in terraces. However, when off-farm income becomes more important for a farm household’s livelihood, the incentive to invest in natural resources (e.g. terracing) declines as the dependence on agriculture decreases (Zimmerer, 1993; Boyd et al., 2000; Hoogeveen and Oostendorp, 2003; Shiferaw et al., 2003). Programme staff in Peru confirmed that the SWC interventions were more successful in the more remote areas where there were no off-farm labour markets. The high labour input needed for terraces is only feasible when labour opportunity costs are low (Chapter 6).

8.4 Conclusions

Our results show that terraces have the potential to increase factor productivity, but whether this is of interest to a farm household depends on factor scarcity and the existing factor markets. Shallow food and labour markets trap farm households within the range of self-sufficiency (Janvry et al., 1991). When the market for agricultural products is imperfect and prices are low, farmers cannot sell their products. Low yields and lack of access to markets mean little incentive for investment in terraces, as yields will not cover the costs unless combined with other improvements that link agricultural production with markets (Rodríguez and Nickalls, 2002; Kuyvenhoven et al., 2004). Equal experiences have been obtained worldwide with costly interventions that had limited impact because of their isolated focus on problems and lack of consideration of marketing aspects. Farmers were reluctant to adopt labour-intensive conservation practices in absence of market incentives that would allow them to offset increased costs (Castaño, 2001).

In order to take advantage of the positive effect of terraces on factor productivity, access to markets has to be improved. When the factor productivity in food production is improved due to technology change, resources can be freed for other cash-generating activities. More labour can be used for off-farm employment, or land and capital can be used for cash crops (Janvry et al., 1991). The first option will lead to extensive agriculture, and thus less willingness among farm households to invest in SWC, the latter option will lead to intensification of agriculture. However, complementary interventions, like public investments in infrastructure or effective market performance, are needed to improve the market access of farm households in order to increase the returns on their resources and products (Ruben et al., 1996; Kuyvenhoven et al., 2004). Also, the credit markets have to be improved to enhance a positive conservation response to increased prices for agricultural products (Hoogeveen and Oostendorp, 2003). Interventions that combat market failures are important for a sustainable rural development and soil management. If SWC practices are promoted without giving attention to the enabling environment, farm households are less motivated to implement these practices, as it is difficult to convert the benefits into increased income or more secure livelihood.

APPENDIX 8.1

Production functions for Pacucha

Dependent variable **Independent variables**	**LN (agricultural production** **β**	**LN (maize production)** **β**
Constant	1.483	1.284
LN (area)	0.326**	0.271**
LN (labour)	0.429***	0.524***
LN (fertiliser)	0.238***	-0.002
Dummy fertiliser	-1.152**	-0.045
% organic fertiliser	0.109	-0.106
% chemical fertiliser	0.342	-0.395
Dummy pesticide	-0.413*	-0.261
Permanent tenure	0.530	0.867
Rainfed	-0.003	-0.225
Slope	-0.431***	-0.165
Soil fertility	0.153	0.107
No stones	0.061	0.097
Bench terrace	-0.058	0.033
IMR (bench terrace= 0)	0.127	0.065
IMR (bench terrace =1)	0.311	0.036
Slow-forming terrace	-0.113	-0.492
IMR (slow-forming terrace=0)	-0.106	-0.234
IMR (slow-forming terrace=1)	0.179	0.285
SWC years	0.084	0.117*
Family size	0.011	0.002
Gender	-0.034	0.085
Age	-0.001	0.003
Education	-0.046	-0.011
Dependency ratio	-0.331	-0.477
Presence	0.015	0.024
Risk taker	0.040	0.325*
Long-term	-0.029	0.111
Off-farm income	-7.4E-6	-2.4E-6
Livestock	-4.6E-5	-8.5E-6
Total farm area	-0.049	-0.040
Incentives: money	4.0E-4	-0.001
Incentives: tools	0.001	0.001
Ayni	0.460	-0.187
Contract labour	0.086	-0.003
Adjusted R^2	0.697	0.580
Prob. (F-statistic)	0.000	0.000

** significant at 0.05 level, ** at 0.01 level, *** at 0.001 level*

APPENDIX 8.2

Production functions for Piuray-Ccorimarca

Independent variables (Dependent variable)	LN (agricultural production β	LN (potato production) β
Constant	3.051	1.786
LN (area)	0.191*	0.387***
LN (labour)	0.367***	0.247**
LN (fertilisers)	0.176*	0.299***
Dummy fertilisers	-0.877	-2.504***
% organic fertiliser	-0.123	0.300
% chemical fertiliser	0.295	0.724*
Dummy pesticide	-0.094	-0.240
Permanent tenure	0.530	1.073
Rainfed	0.102	0.169
Slope	-0.246	-0.022
Soil fertility	0.101	-0.012
No stones	-0.047	0.068
Bench terrace	0.059	0.112
IMR (bench terrace= 0)	0.153	-0.009
IMR (bench terrace =1)	-0.057	0.087
Slow-forming terrace	-0.048	0.118
IMR (slow-forming terrace=0)	-0.242	-0.171
IMR (slow-forming terrace=1)	0.432	0.273
SWC years	-0.014	-0.021
Family size	0.017	0.019
Gender	-0.010	0.040
Age	-0.007	-0.001
Education	-0.003	0.024
Dependency ratio	-0.074	-0.137
Presence	-0.049	0.018
Risk taker	0.028	0.001
Long-term	0.026	-0.075
Off-farm income	7.4E-6	-1.8E-6
Livestock	7.8E-5	2.1E-5
Total farm area	0.153	-0.050
Incentives: money	0.002	0.003*
Incentives: tools	-0.001	-0.001
Ayni	0.210	0.661
Contract labour	-0.085	-0.213
Adjusted R^2	0.553	0.633
Prob. (F-statistic)	0.000	0.000

** significant at 0.05 level, ** at 0.01 level, *** at 0.001 level*

Chapter 9

Conclusions and outlook

9 Conclusions and outlook

Scientists and practitioners are concerned about the threat of soil erosion for agricultural production in developing countries (LDCs). However, it is an often heard complaint that farmers abandon soil and water conservation (SWC) practices once external assistance for implementation is removed. Some argue that one of the reasons that farmers initially adopt and then abandon SWC practices is due to the direct incentives they receive from SWC-oriented programmes (e.g.: Rist and Martin, 1991; Bunch, 1999; Giger, 1999; Winters et al., 2004). In this chapter, the results of previous chapters are put together in order to address the research questions of this thesis. It will be recalled that there were four research questions:

1. What are the physical and subsequent socio-economic effects brought about by on-farm SWC activities and how do the farmers perceive these effects?
2. Which factors are important in the adoption process and what is the influence of the SWC programme incentives?
3. Which socio-economic factors restrain the adoption of SWC practices?
4. What are the implications of these research findings for the use of incentives in SWC interventions?

For this research, an interdisciplinary approach was used, combining agricultural development economics with soil and water conservation, in order to understand the complexity of the processes of adopting SWC practices in the Peruvian Andes. One innovative aspect in this thesis is the analysis of programme impact on adoption behaviour. To our surprise, this aspect has often been neglected in adoption studies. However, the decision about participation in a programme defines the decision made about adoption. Analysing the decision on programme participation first, allows correction of the selectivity bias in the adoption decision due to programme participation. It appears that the adoption pattern for SWC is partly determined by the targeting criteria of programmes promoting SWC. Another innovative aspect of this research is that the effect of SWC was considered not only on agricultural production, but also on factor productivity. This was done because an apparent lack of increase in agricultural production can mask important factor savings: for example an increased labour productivity, or improvement in the fertility of poorly fertile fields.

9.1 The physical and economic effects of bench terraces

Physical effects of bench terraces

As bench terraces modify the slope, water is conserved on the terrace platform and runoff is prevented (Chapter 5). Though bench terraces are very effective in combating soil erosion at field level, one might question the effect of terraces on erosion at watershed level in the research areas, especially in Pacucha. Most of the newly constructed terraces are small and scattered through the watershed (Chapter 4). Furthermore, other researchers have shown that the main factor causing erosion in the Andes is land use, not slope (Harden, 1993; Philip and Reichard, 2002). Hotspots for runoff generation are roads and bare fields. It might thus be more effective to invest in practices like roadside drainage and to promote the planting of hedges on field boundaries to prevent runoff.

Nevertheless, terraces do create benefits for farmers, as they improve cropping conditions and reduce the risk of crop failure (Shively, 1999). The main short-term physical benefit of bench terraces is water conservation. However, at the time of the fieldwork the terraces were still new (2 to 4 years old), and it is possible that their effects on soil fertility had not yet become noticeable (Chapter 5). Production functions (Chapter 8) showed that terraces reduce the negative impact of sloping land on agricultural production. According to farmers surveyed, less labour is needed to grow crops on bench terraces: manual tillage, in particular, becomes easier. However, the bench terraces are too small to use oxen or tractors for tillage. Farmers who till by these means are therefore less interested in bench terraces. Examples are even known of farmers demolishing bench terraces because they wanted to use oxen or tractors for tilling (Wiener et al., 2003; Winters et al., 2004).

Yield measurements (Chapter 5) showed that maize production (grain yield, kg m^{-2}) was significant higher on bench terraces than on steep slopes (> 25%). The combination of bench terraces and organic fertilisers also resulted in a significant increase of grain production, which underlines the importance of complementary technologies. However, with the current crop management, the increased crop density and accompanying yield increase caused by bench terraces were nullified by the area lost due to the terracing. This means that if the improved cropping conditions are not fully exploited, bench terraces may ultimately result in lower yields. Bench terraces should thus be accompanied by intensified crop management, for example through irrigation or the introduction of high-value (cash) crops (Rodríguez and Nickalls, 2002). Unfortunately, the promotion of bench terraces is not usually combined with training on sustainable intensive agronomic technologies.

Profitability of bench terraces

The suggestion in Chapter 5 that bench terraces should be combined with improved agronomic practices and high-value crops was confirmed by the cost-benefit analyses (Chapter 6). When farmers do not take advantage of the improved cropping conditions, bench terraces are unprofitable. Bench terraces create *potential* for an increase of land value. However, the *real* land value only increases if the value of agricultural production increases. Whether bench terraces are financially attractive to a farmer depends on that farmer's opportunity cost of labour. The opportunity cost of labour at break-even point for terracing as an indicator proved to be a useful tool for understanding farmers' rationale. It was found that farmers depending on steep and degraded fields for their food production and income, and with a low opportunity cost of labour (due to few off-farm activities), are willing to invest in terracing, as such an investment improves their livelihood. Farmers who have access to fertile fields in the valley bottom and depend more on their off-farm income (i.e. higher opportunity cost of labour), however, are less interested in terracing, as it is not financially attractive to them. Direct incentives provided by programmes have little effect on the profitability of the terraces. The widespread belief that farmers construct terraces solely in order to receive direct incentives seems to be unfounded, as the investment costs are many times higher than the value of these incentives. So, instead of installing terraces solely to receive the programme incentives, a farmer would do better to generate income by undertaking off-farm activities. The more bench terraces contribute to the improvement of their livelihoods, the more interested farm households are to invest in them.

9.2 Stages, factors and incentives influencing the adoption process

Even though terraces are profitable, this does not guarantee their adoption, as other factors may discourage farm households from implementing them. Initially two stages were defined for the analysis of the adoption process (Chapter 7): programme participation and the adoption decision. The first stage appeared to be crucial for the adoption process, as the main adopters of SWC practices were programme participants that had sloping farmland. Who the participants in the programmes are, and thus who are the adopters, depends on the programmes' targeting criteria (organisation of activities, use of incentives).

In Pacucha, SWC interventions are more recent, which is reflected in the results on programme participation: here, farm households with more land (i.e. more assets) and with a social standing in the community, participate in SWC-oriented programmes. Due to their more extensive network, they are the first to hear about new interventions in their community. In Piuray-Ccorimarca, SWC interventions have been taking place for 20 years, and the diffusion process of SWC practices has spread further. By now, all the farm households are well aware of the different programme activities. Programme participation is determined by personal characteristics, such as level of education and risk aversion, and thus is more demand-driven. The significant negative sign for the education level suggests that farm households with a lower opportunity cost of labour are more interested in participating in an SWC-oriented programme. The programmes help the participating farm households to diversify their income and reduce the risk of crop failure. Risk-averse farm households are therefore also interested in participating in these programmes, and so they too adopt SWC practices. This finding is in contrast with previous studies, which have found that risk-averse farm households are reluctant to adopt SWC practices (Feder et al., 1982; Sinden and King, 1990; Marra et al., 2003).

Another finding that was contrary to the results reported for other studies (Feder et al., 1982; Marsh, 1998; Asfaw and Admassie, 2004) was that farm households characteristics like education or age did not significantly influence the adoption decision. The lack of significance of household characteristics suggests that the programmes decide on the implementation and location of SWC practices. Only when a sub-sample of MARENASS participants was taken, were household characteristics like family size, age, education, risk attitude and time horizon found to be significant for the adoption decision. It seems that the decision to adopt SWC practices is made individually by MARENASS participants, whereas for other programme participants this decision is influenced by technical staff. MARENASS uses a participatory approach whereas the other programmes (PRONAMACHCS and Arariwa) use a more top-down approach, with the SWC practices being installed under the supervision of the technical staff, on marginal land such as steeply sloping rainfed fields. MARENASS participants, however, prefer to install terraces on the less sloping fields near their houses, where vegetables or fodder crops are grown. From a conservation perspective the first approach is preferable, but from an economic point of view it is more interesting for the farm household to implement these practices on the better fields near their houses. As these fields are cultivated more intensively, more benefit can be acquired (Rist and Martin, 1991; Winters et al., 2004). Furthermore, users' rights to these fields are more secure, whereas the degraded fields in the upper parts of a watershed are often on communal land (Chapter 3). During the obligatory fallow period of these fields, the SWC practices are often abandoned and destroyed by the animals herded on this fallow land. In Piuray-Ccorimarca, technical staff of the programmes has great influence on the adoption behaviour of farmers, but the influence of programme incentives is negligible. In Pacucha, programme incentives (i.e. farmer competitions) positively influence the extent of land under SWC practices, but this is not accompanied by an increase of labour investment in the construction. Thus the quality and appropriateness of these SWC practices is questionable. One of the weaknesses of the competitions is that the participating farmers are judged according to the area of terraces, and not according to the quality of the work.

Many NGOs and programmes in the Andes promote SWC practices, and they use different approaches to motivate the farmers. The direct incentives used include food for work, tools for work or cash payment. Farmers themselves confirm that incentives are important in their decision to participate in SWC activities, though it seems that it does not really matter whether these incentives are provided through *faenas* (PRONAMACHCS) or competitions (MARENASS). Farmer competitions are becoming more popular throughout the Andes (IIDA, 2001; Herrera and Valverde, 2003; Kessler, submitted). Most farmers enjoy the competition, though it can create jealousy as well as unrest if the judgements and rewards are considered unfair. The competition itself creates an informal platform for discussion and knowledge exchange, which can be very instructive if this is well organized.

9.3 Socio-economic constraints for adoption of terraces

Why is it that the Incas were so successful in terracing, whereas results of many SWC programmes nowadays are disappointing? During the Inca Empire, agriculture was the main activity, and was even considered as an art that was being constantly refined. Terracing was imposed by the State in order to intensify agriculture and enlarge the area suitable for growing maize – the most important crop, as it was used for religious purposes. There was a guaranteed labour force for the construction of terraces, as the people had to pay taxes by providing labour for the construction of public works (infrastructure, irrigation systems and terraces). At present, however, agriculture is less important for the national economy of Peru (Chapter 3) and the livelihood of an Andean farm household (Bebbington, 1999; Zoomers, 2001). At the same time, opportunity cost of labour has increased, as off-farm employment has become more important for survival. Less labour is therefore invested in agriculture (Cavassa and Bedoya, 2001). Furthermore, there is no longer any permanent state intervention that imposes the construction of terraces. Rather, it is expected that temporary programmes will encourage farmers to implement terraces voluntarily.

Farm households decide on the use of soil resources under the constraints and incentives of the enabling environment (Knowler, 2004). To achieve sustainable adoption of SWC, different conditions have to be met and a farmer should go through several stages in his decision-making and in the adoption process, from perception and recognition to acceptance and adoption (Graaff et al., 2005). Programme incentives can create shortcuts in this process, causing important conditions not to be fulfilled, which results in "unsustainable adoption" or abandonment of SWC (Chapter 2). However, it is rare for all conditions for sustainable adoption to be fulfilled in LDCs – which raises the question of whether conditions are not fulfilled because of the use of programme incentives, or whether the context prevents the conditions from being fulfilled and therefore these incentives are necessary.

In this thesis it has been shown that terraces have the potential to increase agricultural production, land productivity and labour productivity (Chapter 8). However, the desirability of these changes in farm production depends on the functioning of factor and output markets (see also: Ruben et al., 1996). There is no financial benefit from terraces for farm households if there are no markets for the increased yield, the improved land, or the saved labour. Why make an investment if the benefits do not contribute to the household income? Though farm households in the Andes depend on agriculture for their food consumption (Chapters 3 and 4), they rely on off-farm employment providing cash to be able to meet other consumption needs. Marketing and policy-related factors are thus important reasons for adoption or non-adoption of SWC practices (Castaño, 2001), rather than the use of programme incentives. If the functioning of output markets is improved, farmers might be more willing to invest in SWC, as the market will allow them to convert the benefits into cash, thus offsetting the costs. However, if the labour market is improved, there is a risk that farmers will neglect SWC, as they might move away from crop production.

In the current situation, the programmes promoting SWC practices do not have the means, the time or the power to change the institutional context. So why blame these programmes for using incentives to achieve their short-term goals, as their hands are tied to focus on long-term goals (Heredia, 1999)? The influence and potential of many programmes are limited by regional, national and international markets, and political interests. Given the current context in which they work, they are forced to use direct incentives. Of course this does not justify the use of incentives, but it does explain it. Strong institutions are essential for successful SWC interventions. However, attention should also be paid to the influence of sectoral and macro-economic policies at the farm level. As Knowler (2004) puts it: “there is little use in spending large sums on direct farm-level incentives to conserve soils if policies at higher levels inadvertently discriminate against these improvements and can be adjusted at less cost”.

9.4 Implications

Research implications

This research aimed to explain the disappointing results of SWC programmes. Unfortunately, it was limited by time and by the nature of the data. As the process of adopting SWC practices was analysed with only one cross-sectional data set, the influence of risk behaviour and cash flows of farm households was not taken into account. More research should be done with panel data, in order to analyse adoption behaviour of farm households over time and the influence of SWC on the stabilisation of agricultural production and farm income.

Another limitation of the research presented in this thesis is the comparison between a “with” and “without” situation; it would have been better to analyse the impact of SWC with a “before” and “after” comparison, comparing a group of adopters with a group of non-adopters. As the starting point of the “with” and “without” situation are different (both physically in terms of soil productivity as was concluded in chapter 5, as well as economically in terms of farm households’ assets and income strategy), the results may be biased. Intensive data collection during several years is thus needed, to better explain adoption and non-adoption of SWC practices and their impact on rural livelihoods.

The results showed that the SWC-oriented programmes studied play an important role in the adoption of SWC practices, and determine who actually adopts SWC. This finding asks for further research to explain the targeting criteria of these programmes and the decision about programme participation. The low scores for goodness of fit for the programme participation models in this thesis suggest that many factors that determine programme participation were not accounted for. Our understanding of the social processes induced by the programmes has to be improved.

Policy implications

There is no doubt that external interventions stimulate the initial adoption of SWC practices, but whether farm households continue investing in these practices depends on other incentives too – especially market incentives. The intervention of SWC-promoting programmes as well as the market incentives and the agro-ecological conditions (which determine the farming system) differ per community, even per farm household. Therefore, it is not possible to recommend one successful formula for the promotion of SWC. The more farm households depend on agricultural production for their livelihood, the more likely it is that they maintain SWC practices or even continue investing in further implementation. The less they depend on agricultural production, the less they are willing to invest in soil management, as is the case in areas with failing product markets, or in areas with good functioning labour markets. The scarcity of labour and land, which is related to the functioning of the factor markets, also plays a role in the adoption process. New technologies are adopted only if they increase the productivity of the scarcest factor. However, this factor scarcity also differs per region, per community and per farm household. Many factors thus influence the adoption process of SWC practices, and therefore there is no one-size-fits-all solution for the dissemination of SWC practices. Programmes should therefore be decentralised, so the intervention strategies can be adapted to fit the local circumstances. Furthermore, programmes have to realise that providing technical assistance, extension and incentives is not enough to promote SWC; the economic and institutional context has to change as well. Though a change is not always within the capability of a programme, the staff should be aware that this context determines the sustainability of the adoption process, and they should therefore look for market opportunities. For example, if there is no market for food crops, there might be a market for dairy products, and farm households can improve their livestock and animal production by cultivating fodder year-round on terraces.

Programmes and governments that promote SWC, have to be clear about its objective. When the main goal is the conservation of natural resources (i.e. the benefits are for society), permanent governmental intervention might be needed. Local authorities can play an important role in the promotion of SWC, and farm households can be supported by being paid for their environmental services. If the main goal of SWC is to improve rural livelihoods through improved agricultural production, a good understanding of the performance of markets is crucial. Various technologies have to be considered, as not all practices will fit in the existing farming systems. Some incentives may be used to give a boost to the initial adoption (e.g. competitions), but over time they should be reduced. It is necessary to critically evaluate programmes and their staff, as they play an important role in the adoption process. Their targeting criteria have to be well defined, to ensure that they reach the right target group, in line with their objectives. What will most determine whether SWC is successfully adopted is whether favourable macro-economic conditions are created.

Epilogue

September 2003

Santos gets up and stretches his back. He is standing behind his small ramshackle house made of loam, watching his field. He is daydreaming. His land lies on a steep slope; it's a shallow, dry soil full of stones. But one day, this field will be full with terraces. In 1998, MARENASS took him on an excursion to Cusco. He was impressed by the terraces built by his ancestors, the Incas. It was explained to him, how he could build such terraces himself. He started to construct terraces, together with his son and grandson. First a small one, to try. But as they progressed, the terraces got bigger and better. He's proud. Sometimes MARENASS brings visitors, and even tourists come to see his work. He is amazed that so many people are interested in his terraces, but it also stimulates him. He will continue until he terraced the entire slope. What a beautiful sight that will be! And then, one day, when he has money to install an irrigation canal, his terraces will be full with maize, potatoes and beans.

I want to say goodbye to Santos and his wife. I often visited them during my fieldwork, for surveys, questions and measurements. They should be tired of me by now, since they offered me so much and I repaid so little. Santos' wife invites me in the dark kitchen for breakfast. As I sit down on a dirty sheepskin on a wooden bench, she gets me some food: boiled maize with fresh cheese and fried guinea pig. Other guinea pigs – probably brothers and sisters of the fried guinea pig on my plate - , run around my shoes, squeaking, without knowing that soon they will be fried too… Santos' wife talks Quechua to me. She knows I hardly understand any word of it, but she loves making fun of me. Sometimes she repeats her own words in Spanish, so that I can reply. When it's time for me to go, we hug. She starts to cry softly. "Now that you are going, who will visit this old lady?" she asks. "Don't cry, please", I answer her. "One day, I will be back." "Maybe", she says. "But when you come, we will build a house for you so that you can stay and cultivate your potatoes and maize here".

November 2004

Returning to Pacucha feels like coming home. I am anxious to see Santos, the successful farmer of the MARENASS programme. I remember how proud he was with his terraces, and how ambitious he was to terrace his land. Did he continue constructing terraces? I approach his farm. From a distance one can clearly see the well built terraces on the slope. But I cannot discover any new terraces… Santos' wife greets me shyly. "Did you really come back, my daughter?", she asks me. We talk about her health and the grandchildren who live with her. I ask about Santos and his terraces. She shakes her head. "Santos is busy nowadays constructing houses so he can earn some money. He does not have time anymore for the terraces, not even for our garden. We now cultivate in the valley bottom." Indeed, the once beautiful terraced garden now seems abandoned.

Near to the road I find Santos, working hard with some men to construct a house. We chitchat a few minutes. Then I ask Santos whether he is still thinking about constructing new terraces on his field. He looks at me as if I asked him whether the sky is blue. "You know", he says, " MARENASS was a good programme but now we are working with a new one, CARE, on things like health, sanitary facilities and so one. There are other things to do now."

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Summary

As soil erosion is considered to be a major constraint to agriculture and thus to rural development, many efforts are being made to promote soil and water conservation (SWC) practices. However, despite these efforts, the adoption of SWC practices by farmers is often disappointing. This thesis therefore focuses on the reasons for the adoption of SWC practices. The Andes region of Peru was chosen as the fieldwork area because of the importance of SWC in most of its agro-ecological zones, and the extensive experience with SWC practices, interventions and use of incentives. The following research questions were formulated:

1. What are the physical and subsequent socio-economic effects brought about by on-farm SWC activities and how do the farmers perceive these effects?
2. Which factors are important in the adoption process and what is the influence of SWC programme incentives?
3. Which socio-economic constraints restrain the adoption of SWC practices?
4. What are the implications of these research findings for the use of incentives in SWC interventions?

Scientists and agricultural extension officers are often concerned about soil erosion and subsequent declining soil fertility, which are caused by runoff and in the long-term affect productivity. Farmers, however, are often concerned about the short-term effects of runoff on productivity. These concerns are reconciled in the concept of soil productivity, as scientists are interested in how soil erosion affects soil productivity, and farmers in how soil productivity affects crop production. For the biophysical analysis, the research described in this thesis focuses on the impact of SWC practices on soil productivity in terms of crop production. For the economic analysis of SWC practices, two different schools are applied: the evaluation school and the adoption school. The evaluation school tries to quantify the economic impact of different SWC scenarios, making use of cost-benefit analysis. However, profitability is not the only condition resulting in adoption of SWC practices. The adoption school therefore tries to explain the divergences in adoption behaviour between economic agents. There are three main paradigms within adoption theory: the economic constraints paradigm, the innovation-diffusion paradigm, and the adopter perception paradigm. Often, econometric methods are used in empirical research to determine the significant factors influencing the adoption process. As many factors hinder spontaneous adoption, SWC-oriented programmes often provide incentives to promote SWC practices. However, the use of incentives is controversial. Proponents justify the use of incentives in terms of the social benefits of SWC, the market failures, and the fact that farmers are investment-poor. Opponents of incentives argue that they create paternalistic dependency: farmers do not feel responsible and do not develop a conservation attitude. This debate is complicated by the diversity of definitions, as different types of incentives can be distinguished. Many arguments against incentives are against direct incentives, which are designed to have an immediate impact on behaviour and have a discriminating effect, as only adopters receive these incentives. Other indirect incentives can be regulatory measures (fines, taxes), enabling incentives (land security, market development, credit facilities), sectoral incentives (price policy, subsidies) or macro-economic incentives (exchange rate, interest rates).

Rural development in the Andes is affected by the region's inaccessibility, fragility of natural resources and economic structures, marginality of productive activities, and its diversity of agro-

ecological zones and biodiversity. This heterogeneity creates both opportunities and limitations to development. Contemporary agriculture in the Andes typically follows a risk-spreading strategy, rather than being profit-maximising, and is mainly intended to meet farm households' food requirements. The peasant economy has been marginalised by demographic and economic changes. In recent decades, Peru has evolved into a semi-industrial country exporting primary products. The share of agriculture in the Gross National Product has decreased, and since the 1980s Peru has been a net importer of agricultural products. Small-scale farmers in the Andes are excluded from the market due to the low productivity, high transportation costs and high risks of agriculture. Therefore, to assure the cash income they need for expenditure on clothes, food, health and eduction, the farm households also undertake other activities (commercial activities, wage labour, craft, carpentry, production of food products).

The research presented in this thesis was done in two sub-watersheds in the southern part of the Peruvian Andes: Pacucha (Apurímac) and Piuray-Ccorimarca (Cusco). Though both research areas are considered to be poor, there are some important differences between them. The programme interventions in Pacucha are more recent, as this area suffered from extreme guerrilla violence in the 1980s. In Piuray-Ccorimarca, the programme interventions are more intensive and diffuse. Another difference is that farm households in Piuray-Ccorimarca are relatively well-off. They sell a larger percentage of their agricultural produce on the market, and they have a higher off-farm income than farm households in Pacucha.

The Ministry of Agriculture launched two programmes promoting SWC practices: PRONAMACHCS and the recent MARENASS pilot scheme. The former is characterised by knowledge transfer, technical assistance and a top-down approach, the latter by a participatory bottom-up approach, farmer-to-farmer extension and farmers' competitions. A third organisation promoting SWC practices is the NGO Arariwa, which used to pay farmers in the past for implementing SWC practices. PRONAMACHCS has activities in both research areas, MARENASS is active in Pacucha and Arariwa is active in Piuray-Ccorimarca.

During fieldwork for this thesis, the impact of terraces on soil productivity and crop yield was evaluated by soil analyses and yield measurements in farmers' fields in Pacucha. The main (short-term) benefit of terraces was found to be the increased water availability in the soils, which allows an increased crop density and subsequent higher yields. As organic fertilisers are mainly applied on less fertile fields, it is difficult to see any positive effect of fertilisation. Crop yields on terraces are about 20% higher than on the adjacent sloping fields. However, the area lost due to terracing is also about 20%, nullifying the positive effect on yield. Terraces improve cropping conditions, but if no advantage is taken of this, there will be no effect. Therefore, terracing has to be combined with changes in crop management, such as irrigation or the growing of crops with a high market value.

The results of the yield measurements were used for a cost-benefit analysis of the same terraces. It was found that terraces are not profitable if the farmer does not take advantage of the improved cropping conditions. Whether terraces are financially attractive for farmers depends on the farmer's personal characteristics, especially the opportunity cost of labour. The value of labour at break-even point was calculated. In most cases the value of labour invested in terracing was positive, but below the market wage. It was also found that the direct incentives the farmers received affected the profitability of the terraces only slightly, as the value of the labour investment of farmers is many times higher than the value of the direct incentives received. Though direct incentives may initially encourage farmers to implement terraces, they do not make terraces more financially attractive to them.

Even though terraces are profitable, this is no guarantee that they will be adopted, as other factors may discourage farm households from implementing them. Surveys were done in the two research areas and the data were analysed with econometric methods, in order to elucidate the adoption process. The analysis was initially split up into two stages, representing two decisions: (1) programme participation – whether to participate in a programme that promotes SWC, and (2) adoption decision – whether to implement SWC practices on the farmland. Also the adoption effort – the investment made (labour or land) in the implementation of SWC practices – was estimated. The *decision to participate in a programme* is considered to be the first stage, as this participation will increase farmers' knowledge of SWC and influence their attitude towards SWC. In Piuray-Ccorimarca, programmes have promoted SWC practices for more than 20 years and by now all farm households are well aware of their activities. Programme participation in this area depends on personal characteristics (a low education level and risk aversion) and thus is demand-driven. The programmes help farm households with low opportunity costs of labour to diversify their income and reduce risk. In Pacucha, the SWC interventions are more recent. Farm households with more land and a higher social standing participate. Due to their social standing they have a more extensive network and are the first to hear about new interventions in their community. In general, the *adopters of SWC* practices are programme participants with sloping farmland. The great significance of programme participation reveals the strong influence of programmes on the adoption decision. Farm households participating in MARENASS decide individually on the implementation of SWC practices, and they install bench terraces on the gently sloping fields near their houses. The adoption decision of farm households participating in other programmes is influenced greatly by programme staff, and results in the installation of slow-forming terraces and infiltration ditches on the extensively cultivated degraded and steeply sloping land. Direct incentives have not resulted in a change in *adoption effort*, except for the farmer competitions in the MARENASS programme that have led to farm households constructing terraces on much of their land, as it is the area under terraces that counts in the competition. However, the quality of these terraces is dubious, as they have not led to an increase in labour investment.

It is generally assumed that an increased productivity or output stability contributes to the willingness of farm households to adopt resource-conserving practices. Therefore, the impact of terraces on factor productivity (land, labour and fertilisers) was analysed by estimating production functions at household level. It was found that the main determinants of the agricultural production in both research areas are labour, land, fertilisers and slope. Production is influenced positively by the production inputs, but negatively by the slope. Household characteristics like education and age are less important, indicating that management skills do not have a large influence on the total output. Though terraces do not significantly increase the agricultural output, they do reduce the negative effect of the slope. The effects of terraces on output and productivity are more pronounced for farm households with mainly gently and steeply sloping farmland. The effects are more positive in Pacucha, where bench terraces are the main SWC practices, than in Piuray-Ccorimarca, where SWC practices mainly consist of slow-forming terraces on steep, poorly productive land. The terraces also result in a significant increase of labour productivity in Pacucha. The marginal product of land was found to be lower on farms with terraces, but the marginal product of labour was higher in Pacucha. In Piuray-Ccorimarca, the exact opposite was found: the marginal product of land was higher on farms with terraces, but the marginal product of labour was lower than on farms without terraces. This opposite effect was caused by the differences in factor scarcity and factor markets between the two areas. In Piuray-Ccorimarca, land is scarcer but more capital is available. Agriculture is more intensive, which is expressed by a larger labour input in cropping activities, and heavier application of chemical fertilisers. This high external input farming system is defined by the crop potato, the scarcity of land and the better-developed markets in the area of Piuray-Ccorimarca. Pacucha has to cope with failing labour and output markets because of its bad accessibility. Despite the potential of terraces to increase maize production in Pacucha, the farmers decided to keep the production at the same level, while using less labour. This resulted in the increased crop labour productivity. These findings show that terraces have the potential to increase agricultural production and factor productivity, but whether this is of interest to a farm household depends on the existing factor markets. When SWC practices are promoted, attention has to be given to the enabling institutional environment.

The research demonstrates that the attractiveness of SWC practices for a farm household in the Peruvian Andes is very site- and household-specific. The more households depend on agriculture for their livelihood and the lower their opportunity cost of labour, the more they can benefit from SWC. Though external intervention by SWC-oriented programmes is the key driver of adoption, programme incentives were shown to be less important than expected. Market incentives, on the other hand, seem to be an important determinant of sustainable adoption. Disparagers of the use of programme incentives argue that they accelerate the decision-making process, resulting in adoption being unsustainable because important conditions for sustainable adoption are not considered. However, it may also be the case that as these conditions for sustainable adoption cannot be created, programme incentives are important to achieve any adoption, as without them, nothing will happen. Nevertheless, for SWC practices to be adopted, it is essential to pay attention to the institutional context and market constraints. As the situation differs per region, SWC interventions should be decentralised. If the main goal of SWC intervention is the conservation of natural resources, permanent intervention by local authorities can be considered. However, if the objective of SWC intervention is to improve rural livelihoods through increased agricultural production, a good understanding of the existing markets is crucial.

Samenvatting

In ontwikkelingslanden wordt veel moeite gedaan om bodem- en waterconservering (BWC) te bevorderen, aangezien bodemerosie als een belangrijke beperking voor landbouw wordt gezien, en als gevolg daarvan ook voor de rurale ontwikkeling. Ondanks deze inspanningen is de adoptie van BWC maatregelen door boeren vaak teleurstellend. Dit proefschrift behandelt de redenen voor adoptie of verwerping van BWC maatregelen. De Andes regio in Peru is als onderzoeksgebied gekozen, aangezien BWC aldaar in de meeste agro-ecologische zones belangrijk is, en men hier veel ervaring heeft met BWC maatregelen, interventies en het gebruik van *incentives*. De onderzoeksvragen zijn als volgt geformuleerd:

1. Wat zijn de fysische en vervolgens sociaal-economische effecten van BWC activiteiten op een boerenbedrijf, en hoe waarderen boeren deze effecten?
2. Welke fasen en factoren zijn belangrijk in het adoptie proces en wat is de invloed van *incentives* hierop?
3. Welke sociaal-economische beperkingen houden adoptie van BWC maatregelen tegen?
4. Wat zijn de implicaties van dit onderzoek voor het gebruik van *incentives* in BWC-interventies?

Wetenschappers en voorlichters bekommeren zich vaak over bodemerosie, veroorzaakt door afstromend water, en de daaraan gerelateerde dalende bodemvruchtbaarheid, wat op lange termijn de productiviteit aantast. Boeren zijn echter vaak bezorgd over de korte termijn effecten van afstromend water op de productiviteit. Deze twee aspecten worden verenigd in het concept bodemproductiviteit, aangezien wetenschappers geïnteresseerd zijn in hoe bodemerosie bodemproductiviteit beïnvloedt, en boeren hoe bodemproductiviteit de gewasopbrengst beïnvloedt. De bio-fysische analyse van het onderzoek zoals beschreven in dit proefschrift behandelt het effect van BWC maatregelen op bodemproductiviteit in de vorm van de gewasopbrengst. Twee verschillende benaderingen zijn gebruikt voor de economische analyse van de BWC maatregelen: de evaluatie school en de adoptie school. De evaluatie school kwantificeert de economische impact van verschillende BWC scenario’s met behulp van kosten-baten analyses. Maar rendabiliteit leidt niet automatisch tot adoptie van BWC maatregelen. De adoptie school probeert afwijkingen in adoptie gedrag tussen individuen te verklaren. Er bestaan drie paradigma’s binnen de adoptie theorie: het paradigma van economische restricties, het paradigma van innovatie-diffusie en het paradigma van de perceptie van de gebruiker. In empirisch onderzoek worden vaak econometrische methodes gebruikt om de significante factoren te bepalen die het adoptie proces beïnvloeden. Aangezien veel factoren spontane adoptie verhinderen, worden *incentives* vaak gebruikt door programma’s die BWC bevorderen. Dit gebruik van *incentives* is echter omstreden. Voorstanders rechtvaardigen het gebruik van *incentives* vanwege de sociale baten van BWC, markt-imperfecties, en het feit dat boeren vaak te arm zijn om te kunnen investeren. Tegenstanders van *incentives* vinden dat deze een paternalistische afhankelijkheid creëert: boeren voelen zich niet verantwoordelijk en ontwikkelen geen positieve houding ten opzichte van milieubeheer. De verscheidenheid aan definities bemoeilijkt dit debat, aangezien verschillende typen *incentives* onderscheiden kunnen worden. Veel argumenten tegen *incentives* zijn eigenlijk tegen directe *incentives*, die worden ontworpen om een direct effect op gedrag te veroorzaken; deze hebben een discriminerend effect aangezien alleen de nieuwe gebruikers deze *incentives* ontvangen. Andere indirecte *incentives* kunnen regulerende maatregelen zijn (boetes, belasting), *incentives* die gunstige

omstandigheden voor adoptie scheppen (landrechten, marktontwikkeling, krediet verlening), sectorale *incentives* (prijsbeleid, subsidies) of macro-economische *incentives* (wisselkoers, rentekoers).

De ontoegankelijkheid, de fragiliteit van natuurlijke hulpbronnen en economische structuur, de marginaliteit van productie activiteiten, en de diversiteit van agro-ecologische zones en biodiversiteit in de Andes houden de rurale ontwikkeling van deze regio tegen. De heterogeniteit creëert zowel mogelijkheden als beperkingen voor ontwikkeling. Hedendaagse landbouw in de Andes wordt eerder getypeerd door een strategie van risico-spreiding dan door winst-maximalisatie, en de landbouw is voornamelijk bedoeld om de voedselvoorziening van het boerenhuishouden veilig te stellen. Door demografische en economische veranderingen is de landbouweconomie gemarginaliseerd. Peru is in de afgelopen decennia veranderd in een semi-industriëel land dat primaire producten exporteert. Het aandeel van landbouw in het Bruto Nationaal Product is gedaald, en sinds de jaren ’80 is Peru een netto importeerder van agrarische producten. Kleinschalige boeren in de Andes zijn buitengesloten van de markt vanwege de lage productiviteit, hoge transportkosten en hoge risico’s binnen de landbouw. Daarom ontplooien veel boerenhuishoudens activiteiten buiten de landbouw (commerciële activiteiten, loonarbeider, handwerk, houtbewerking, bereiding van voedselproducten) om hun inkomsten veilig te stellen, die nodig zijn om de uitgaven aan kleding, voedsel, gezondheidszorg en onderwijs te kunnen bekostigen.

Het onderzoek zoals in dit proefschrift beschreven, is uitgevoerd in twee stroomgebieden in het zuidelijk deel van de Peruaanse Andes: in Pacucha (Apurímac) en Piuray-Ccorimarca (Cusco). Hoewel beide gebieden als arm worden beschouwd, zijn er een aantal belangrijke verschillen. In Pacucha zijn de interventies van programma’s recenter, aangezien deze regio geteisterd werd door extreem geweld tijdens de guerilla in de jaren ’80. De interventies van programma’s in Piuray-Ccorimarca zijn intenser en wijder verspreid. Bovendien zijn de boerenhuishoudens in Piuray-Ccorimarca relatief rijker. Zij verkopen een groter percentage van hun agrarische productie op de markt en hebben een hoger inkomen buiten de landbouw dan de boerenhuishoudens in Pacucha.

Het ministerie van landbouw heeft twee programma’s gelanceerd die BWC maatregelen promoten: PRONAMACHCS en het recentere MARENASS. Het eerste programma wordt gekenmerkt door kennisoverdracht, technische assistentie en een hiërarchische ‘top-down’ benadering. Het tweede programma wordt gekenmerkt door een participatieve ‘bottom-up’ benadering, voorlichting door boeren zelf gegeven, en competities onder boeren. Een derde organisatie die ook BWC maatregelen promoot is de NGO Arariwa, welke in het verleden boeren heeft betaald voor het aanleggen van BWC maatregelen. PRONAMACHCS heeft activiteiten in beide gebieden, MARENASS in Pacucha en Arariwa in Piuray-Ccorimarca.

Het effect van terrassen op de bodemproductiviteit en gewasopbrengst is tijdens het veldwerk in Pacucha geëvalueerd aan de hand van bodemanalyses en oogstmetingen in velden van boeren. De toegenomen beschikbaarheid van water in de bodem is het voornaamste voordeel van terrassen (op korte termijn), wat een hogere plantdichtheid mogelijk maakt en als gevolg hiervan ook een hogere opbrengst. Enig positief effect van organische mest was moeilijker vast te stellen omdat organische mest voornamelijk op de minder vruchtbare velden wordt toegediend. De gewasopbrengsten op de terrassen zijn ongeveer 20% hoger dan op de aangrenzende velden op een helling. Maar het oppervlak wat door het aanleggen van terrassen verloren is gegaan, is ook ongeveer 20%, wat het positieve effect van terrassen op de gewasopbrengst ongedaan maakt. Terrassen verbeteren de teeltomstandigheden voor een gewas, maar als hier geen gebruik van gemaakt wordt, zullen terrassen geen effect op de opbrengst hebben. Terrassen moeten dus gecombineerd worden met veranderingen in het teeltsysteem, zoals irrigatie of het verbouwen van gewassen met een hogere marktwaarde.

De resultaten van de oogstmetingen zijn voor de kosten-baten analyse van dezelfde terrassen gebruikt. De resultaten tonen aan dat terrassen niet rendabel zijn wanneer de boer geen voordeel haalt uit de verbeterde teeltomstandigheden. Het hangt van de persoonlijke omstandigheden van de boer af, in het bijzonder van de kosten van alternatieve aanwending van zijn arbeid, of de terrassen ook financieel aantrekkelijk zijn. De waarde van zijn arbeid is berekend voor het punt dat de kosten en baten gelijk zijn (*break-even point*). De waarde van de arbeid geïnvesteerd in de aanleg van de terrassen was in de meeste gevallen positief, maar wel onder de marktwaarde van arbeid. Het bleek ook dat de directe *incentives* die boeren ontvingen de rendabiliteit nauwelijks beïnvloedden, aangezien de waarde van de arbeid geïnvesteerd in de aanleg veel hoger is dan de waarde van deze *incentives*. Hoewel *incentives* boeren in het begin kunnen aanmoedigen om terrassen aan te leggen, maken deze *incentives* de terrassen nauwelijks financieel aantrekkelijker voor hen.

Ook al zijn de terrassen rendabel, dit is geen garantie dat ze ook worden geaccepteerd, aangezien andere factoren boerenhuishoudens kunnen ontmoedigen om terrassen aan te leggen. In beide onderzoeksgebieden werden enquêtes uitgevoerd en de gegevens werden met econometrische methodes geanalyseerd om het adoptie proces te doorgronden. De analyse werd in eerste instantie in twee fasen opgesplitst, die verschillende beslissingen representeren: (1) programma participatie - of het huishouden mee doet aan een programma dat BWC promoot, en (2) adoptie beslissing – of het huishouden BWC maatregelen op eigen land aanlegt. Ook de adoptie inspanning – de investering (arbeid of land) die het huishouden maakt in het aanleggen van BWC maatregelen – werd geschat. De *beslissing om aan een programma mee te doen* wordt als eerste fase beschouwd, aangezien deelname de kennis van boeren over BWC doet toenemen en hun houding ten opzichte van BWC zal beïnvloeden. Programma's in Piuray-Ccorimarca promoten BWC al meer dan 20 jaar en ondertussen zijn alle boerenhuishoudens goed op de hoogte van de activiteiten. In dit gebied hangt programma participatie van persoonlijke kenmerken af (een laag opleidingsniveau en risico aversie) en deelname wordt dus bepaald door de vraag. De programma's helpen boerenhuishoudens met lage opportuniteitskosten voor hun arbeid om hun bronnen van inkomsten te variëren en om hun risico te verlagen. De BWC interventies in Pacucha zijn recenter. Boerenhuishoudens met meer land en een hogere sociale positie nemen deel aan de programma's. Dankzij hun sociale positie hebben zij een wijder netwerk en zijn dus de eersten die over nieuwe interventies in hun gemeenschap horen. Over het algemeen zijn de gebruikers van BWC de huishoudens die aan een programma deelnemen en hellend akkerland hebben. De sterke significantie van programma deelname onthult de sterke invloed van programma's op de adoptie beslissing. Boerenhuishoudens die in MARENASS deelnemen, beslissen individueel over de aanleg van BWC maatregelen wat resulteert in de aanleg van bank terrassen op de minder steile akkers dichtbij hun huizen. De adoptie beslissing van boerenhuishoudens die aan andere programma's deelnemen wordt sterk beïnvloed door het personeel van de programma's, resulterend in de aanleg van langzaam-vormende terrassen en infiltratie greppels op gedegradeerde en steile akkers met extensieve teelt. Directe *incentives* hebben de adoptie inspanning, of investering, niet veranderd, behalve de competities onder boeren van MARENASS, wat in een groter areaal met nieuw aangelegde terrassen resulteerde aangezien de hoeveelheid land met terrassen voor de jurering telde. De kwaliteit van de terrassen is echter dubieus, aangezien de competities niet in een hogere investering van arbeid resulteerde.

Over het algemeen wordt aangenomen dat toenemende productiviteit van productie factoren of hogere productie stabiliteit bijdraagt aan de bereidheid van boerenhuishoudens om maatregelen voor het behoud van hulpbronnen te adopteren. De invloed van terrassen op factor productiviteit (van land, arbeid en kunstmest) is daarom geanalyseerd door productie functies op huishoudniveau te schatten. Het bleek dat in beide gebieden arbeid, land, kunstmest en de helling de belangrijkste factoren van agrarische productie waren. Kenmerken van huishoudens zoals opleiding en leeftijd zijn minder belangrijk, wat aangeeft dat vaardigheden in management minder belangrijk zijn voor de totale opbrengst. Het positieve effect van terrassen op de agrarische opbrengst is niet significant, maar ze verminderen wel de negatieve invloed van de helling. De effecten van terrassen op opbrengst en productiviteit zijn duidelijker voor boerenhuishoudens met hellend akkerland. De effecten zijn positiever in Pacucha, waar *bankterrassen* de meeste voorkomende BWC maatregelen zijn, dan in Piuray-Ccorimarca, waar BWC maatregelen vooral uit *langzaam-vormende* terrassen op steil en marginaal land bestaan. De terrassen resulteerden in een significante toename van de arbeidsproductiviteit in Pacucha. Het marginale product van land bleek lager te zijn op boerderijen met terrassen in Pacucha, maar het marginale product van arbeid was hoger. In Piuray-Ccorimarca werd exact het tegenovergestelde gevonden: het marginale product van land was hoger op boerderijen met terrassen, maar het marginale product van arbeid was lager dan op boerderijen zonder terrassen. Dit tegenovergestelde effect werd veroorzaakt door verschillen in factor schaarste en factor markten tussen de twee gebieden. Land is schaarser maar kapitaal is meer beschikbaar in Piuray-Ccorimarca. Landbouw is intensiever, hetgeen wordt uitgedrukt in een hogere arbeidsinput in teeltactiviteiten en een hogere toediening van kunstmest. Dit boerenbedrijfssysteem met een hoge externe input wordt bepaald door de teelt van aardappel, de schaarste van land en beter ontwikkelde markten in de regio rondom Piuray-Ccorimarca. Vanwege de slechte bereikbaarheid heeft Pacucha te kampen met een falende arbeidsmarkt en een falende markt voor agrarische producten. Ondanks de potentie van terrassen om de maïs productie in Pacucha te verhogen, besluiten de boeren om de productie op hetzelfde niveau te houden, maar met een lagere input van arbeid. Dit resulteerde in een verhoogde productiviteit van arbeid in de akkerbouw. Deze resultaten geven aan dat terrassen wel de potentie hebben om de agrarische productie en factor productiviteit te verhogen, maar het hangt van de bestaande factor markten af of dit voor de boerenhuishoudens interessant is. Het is belangrijk dat aandacht gegeven wordt aan deze institutionele context, wanneer BWC maatregelen bevorderd worden.

Dit onderzoek toont aan dat de aantrekkelijkheid van BWC maatregelen voor een boerenhuishouden in de Peruaanse Andes erg afhankelijk is van de plaats en het huishouden. Hoe meer de huishoudens afhankelijk zijn van landbouw voor hun levensonderhoud en hoe lager hun kosten van alternatieve aanwending van arbeid, hoe meer zij van BWC kunnen profiteren. Hoewel externe interventie door programma's die BWC promoten de belangrijkste drijfkracht van adoptie is, zijn de *incentives* van deze programma's minder belangrijk dan gedacht. *Incentives* van markten blijken veel belangrijker te zijn voor duurzame adoptie. Tegenstanders van het gebruik van *incentives* beargumenteren dat deze het beslissingsproces versnellen, wat in een onduurzame adoptie resulteert omdat belangrijke voorwaarden voor duurzame adoptie worden genegeerd. Maar het kan ook zo zijn dat deze voorwaarden voor duurzame adoptie niet gecreëerd kunnen worden, en *incentives* daarom belangrijk zijn om adoptie te bereiken, aangezien zonder deze *incentives* niks zou gebeuren. Niettemin is het essentieel om aandacht aan de institutionele context en beperkingen van de markt te geven om de adoptie van BWC maatregelen te bevorderen. Aangezien de situatie per regio verschilt, moeten BWC interventies gedecentraliseerd worden. Wanneer het behoud van natuurlijke hulpbronnen het belangrijkste doel van BWC interventie is, kan een permanente interventie door de lokale autoriteiten overwogen worden. Maar als het doel van BWC interventie het verbeteren van het levensonderhoud in rurale gebieden door middel van verhoogde agrarische productie is, is een goed begrip van de bestaande markten cruciaal.

Resumen

La erosión del suelo es considerada como una restricción mayor a la agricultura y así al desarrollo rural. Por eso, están haciéndose muchos esfuerzos promoviendo las prácticas de conservación de suelos y aguas (CSA). Sin embargo, la adopción de las prácticas de CSA por agricultores está deceptionante muchas veces, a pesar de estos esfuerzos. Por consiguiente esta tesis enfoca en las razones de la adopción de prácticas de CSA. La región de Andes de Perú era escogida como el área de investigación debido a la importancia de CSA en la mayoría de sus zonas agro-ecológicas, y la experiencia extensa con las prácticas de CSA, con las intervenciones y con el uso de incentivos. Las preguntas de la investigación fueron formuladas como siguiente:

1. ¿Cuales son los efectos físicos y socio-económicos que se traen por las actividades de CSA acerca a la finca, y cómo perciben los agricultores estos efectos?
2. ¿Qué factores son importantes en el proceso de adopción y cual es la influencia de los incentivos de las programas de CSA?
3. ¿Qué restricciones socio-económicos refrenan la adopción de prácticas de CSA?
4. ¿Cuales son las implicaciones de los resultados de ésta investigación para el uso de incentivos en las intervenciones de CSA?

Científicos y personal de la extensión agrícola se preocupan muchas veces por la erosión del suelo y, por consequencia, el descenso de la fertilidad del suelo, que son causados por el escorrentía, y afectan la productividad en el término largo. Agricultores, sin embargo, se preocupan generalmente por los efectos de escorrentía en la productividad a corto plazo. Estas preocupaciones diferentes se reconcilian en el concepto de productividad del suelo, cuando los científicos están interesados en cómo la erosión afecta la productividad del suelo, y los agricultores en cómo la productividad del suelo afecta la cosecha. Para el análisis biofísico, la investigación en esta tesis enfoca en el impacto de prácticas de CSA en la productividad del suelo, lo que es la cosecha. Para el análisis económico de prácticas de CSA, dos escuelas diferentes son aplicadas: la escuela de la evaluación y la escuela de adopción. La escuela de la evaluación intenta cuantificar el impacto económico de intervenciones de CSA diferentes, usando el análisis del costo-beneficio. Sin embargo, la rentabilidad no es la única condición que causa adopción de prácticas de CSA. La escuela de adopción intenta explicar las divergencias en el comportamiento de adopción entre los agentes económicos. Hay tres paradigmas principales dentro de la teoría de adopción: el paradigma de restricciones económicos, el paradigma de innovación-difusión, y el paradigma de percepción del usuario. A menudo, se usan los métodos econometricos en la investigación empírica para determinar los factores significantes que influyen el proceso de adopción. Ya que tantos factores impiden la adopción espontánea, los programas orientados al CSA muchas veces proporcionan los incentivos para promover las prácticas de CSA. Sin embargo, el uso de incentivos es discutido. Los defensores justifican el uso de incentivos por lo que se refiere a los beneficios sociales de CSA, los fracasos del mercado, y el hecho que agricultores son inversión-pobres. Los oponentes de incentivos defienden que ellos crean una dependencia paternalista: agricultores no se sienten responsables y no desarrollan una actitud de conservación. Este debate es complicado por la diversidad de definiciones, como se puede distinguir diferentes tipos de incentivos. Muchos argumentos contra los incentivos están contra incentivos directos que se diseñan para tener un impacto inmediato en el comportamiento de agricultores y que tienen un efecto diferenciado como sólo los usuarios reciban estos incentivos. Otros incentivos indirectos pueden ser las medidas

reguladores (las multas, impuestos), incentivos facilitadores (la seguridad de la tierra, el desarrollo del mercado, los medios del crédito), los incentivos sectoriales (la política del precio, subsidios) o los incentivos macroeconómicos (el tipo de cambio, proporciones de interés).

El desarrollo rural en los Andes es afectado por la inaccesibilidad de la región, la fragilidad de los recursos naturales y de las estructuras económicas, la marginalidad de actividades productivas, y su diversidad de zonas agro-ecológicas y biodiversidad. Esta heterogeneidad crea tanto oportunidades como limitaciones al desarrollo. La agricultura contemporánea en el Andes sigue una estrategia extendiendo el riesgo, en lugar de maximizar ganancia, y intenta principalmente de cubrir los necesidades de consumo de la familia agricultora. La economía campesina se ha marginado por los cambios demográficos y económicos. En las recientes décadas, Perú ha evolucionado en un país semi-industrial que exporta los productos primarios. La porción de agricultura en el Producto Nacional Grueso ha disminuido, y Perú ha sido un importador neto de productos agrícolas desde que los años 1980s. En los Andes las familias campesinas de pequeña escala son excluidos del mercado debido a la productividad baja, los costos altos del transporte y riesgos altos en la agricultura. Por consiguiente, para asegurar el ingreso las familias campesinas necesitan para los gastos en ropas, comida, salud y educación, la familia agricultora también emprende otras actividades (actividades comerciales, mano de obra, artensanía, carpintería, producción de productos alimentarios).

La investigación presentada en esta tesis se hizo en dos micro-cuencas en la parte sur del los Andes peruanos: Pacucha (Apurímac) y Piuray-Ccorimarca (Cusco). Aunque los dos áreas se considera como pobres, hay algunas diferencias importantes entre ellos. Las intervenciones de programas son más recientes en Pacucha, como este área sufría violencia extrema del guerrilla en los años 1980s. En Piuray-Ccorimarca, las intervenciones de programas son más intensivas y difusas. Otra diferencia es que las familias campesinos en Piuray-Ccorimarca son relativamente bien situadas. Ellos venden un porcentaje más grande de sus productos agrícolas en el mercado, y ellos tienen un ingreso de actividades non-agricultores más alto que las familias agricultores en Pacucha.

El Ministerio de Agricultura lanzó dos programas que promueven las prácticas de CSA: PRONAMACHCS y más reciente el programa piloto MARENASS. El anterior se caracteriza por el traspaso de conocimiento, asistencia técnica y un enfoque arriba-abajo, el último por un enfoque participativo de abajo-arriba, extensión de campesino-a-campesino y concursos campesinos. Un tercer organización promoviendo prácticas de CSA es el ONG Arariwa que pagaba al agricultores para ejecutar las prácticas de CSA en el pasado. PRONAMACHCS tiene actividades en los dos áreas de la investigación, MARENASS en Pacucha y Arariwa en Piuray-Ccorimarca.

Para este tesis, se evaluó el impacto de terrazas en la productividad del suelo y en la cosecha por los análisis del suelo y medidas de cosecha en los terrenos de agricultores en Pacucha. El beneficio principal (a corto plazo) de las terrazas fue la aumentada disponibilidad de agua en el suelo permitiendo una aumentada densidad de plantas y por consiguiente los rendimientos más altos. Puesto que los fertilizantes orgánicos son aplicados principalmente en los terrenos de menos fertilidad, es difícil de notar cualquier efecto positivo de fertilisantes. El rendimiento en las terrazas es aproximadamente 20% superior que el rendimiento en los terrenos vecinos en pendiente. Sin embargo, el área perdida debido a la construcción de terrazas es aproximadamente 20% también, anulando el efecto positivo en el rendimiento. Las terrazas mejoran las condiciones para el cultivo, pero si no se las aprovecha, no habrá ningún efecto. Por consiguiente, las terrazas tienen que ser combinado con cambios en la gestión de cultivo, como la aplicación de riego o cultivos con un valor mejor del mercado.

Los resultados de las medidas de cosecha fueron utilisados para un análisis del costo-beneficio de las mismas terrazas. Se afirmó que las terrazas no son aprovechables si el agricultor no se aprovecha de las condiciones mejoradas para el cultivo. Depende de las características personales de la familia campesina, sobre todo los costos de oportunidad del mano de obra, si las terrazas son atractivas financialamente para las familias campesinas. El valor del mano de obra al punto de equilibrio era calculado. En la mayoría de los casos el valor del mano de obra invertido en las terrazas era positivo, pero debajo del salario mercantil. También resultó que los incentivos directos que los agricultores recibieron para las terrazas afectaron solamente ligeramente su rentabilidad, como el valor del mano de obra de agricultores es superior al valor de los incentivos directos recibidos. Aunque los incentivos directos pueden estimular los agricultores de construir terrazas inicialmente, los mismos no mejoran la attracción financiera de las terrazas.

Aunque las terrazas son rentables, ésta es ninguna garantía que los agricultores las adoptarán, ya que otros factores pueden impedir las familias campesinas de efectuarlas. Se ejecutó encuestas en las dos áreas de la investigación y se analizó los datos con los métodos econometricos para elucidar el proceso de adopción. Al inicio, se dividió el análisis en dos fases, representando dos decisiones: (1) la participación en un programa – si la familia campesina participa en un programa que promueve CSA, (2) la decisión de adopción – si ejecuta las prácticas de CSA en su terreno. Tambien se estimó el esfuerzo de adopcion – la inversión hecho (mano de obra o tierra) en la aplicación de prácticas de CSA. Se considera la *decisión para participar en un programa* como primero etapa, ya que esta participación aumentará el conocimiento de las familias campesinas sobre CSA e influirá su actitud hacia CSA. En Piuray-Ccorimarca, los programas han promovido las prácticas de CSA durante más de 20 años y ahora todos las familias campesinas son bien conscientes de sus actividades. En este área, la participación en programas depende de las características personales (bajo nivel de educación y aversión de riesgo) y así es estimulado por la demanda. Los programas ayudan las familias campesinas con costos de oportunidad bajos de mano de obra para diversificar su ingreso y reducir el riesgo. En Pacucha, las intervenciones de CSA son más recientes. Las familias campesinas con más terreno y una posición social más alta participen. Debido a su posición social ellos tienen una red más extensa y son el primero en oír hablar de las nuevas intervenciones en su comunidad. En general, los usuarios de prácticas de CSA son los participantes de los programas con terreno en pendiente. La gran importancia de participación en un programa revela la influencia fuerte de programas en la decisión de adopción. Familias campesinas que participan en MARENASS deciden individualmente en la aplicación de prácticas de CSA, y ellos instalan las terrazas de absorción en los terrenos con poco pendiente acerca de sus casas. La decisión de adopción de familias campesinas que participan en otros programas se influencia grandemente por el personal del programa, y se resulta en la instalación de terrazas de formación lenta y zanjas de infiltración en el terreno deteriorado, extensivamente cultivado y con fuerte pendiente. Los incentivos directos no resultan en un cambio en el esfuerzo de adopción, con excepción de los concursos campesinos del programa MARENASS que resultaron en un área mayor con terrazas construidas por las familias campesinas, puesto que se cuenta el área bajo terrazas para los concursos. Sin embargo, la calidad de estas terrazas es dudosa, porque los concursos no han llevado a un aumento en la inversión del mano de obra.

Generalmente se supone que una productividad aumentada o un rendimiento estable contribuye a la buena voluntad de las familias campesina para adoptar prácticas conservandos los recursos. Por consiguiente, se analizó el impacto de terrazas en la productividad de factor (la tierra, mano de obra y fertilizantes) estimando las funciones de producción al nivel de la familia campesina. Fue encontrado que los determinantes principales de la producción agrícola en las dos áreas de la investigación son mano de obra, terreno, fertilizantes y pendiente. Los insumos influyen positivamente la producción, pero el pendiente negativamente. Las características de la familia campesina como la educación y edad son menos importantes, indicando que ese capacidades de administración no tienen una influencia grande en la producción agrícola. Aunque las terrazas no aumentan la producción agrícola significativamente, ellos reducen el efecto negativo del pendiente. Los efectos de terrazas en el rendimiento y productividad son más pronunciados para las familias campesinas con terreno con pendiente. Los efectos son más positivos en Pacucha dónde las terrazas de absorción son las prácticas de CSA principales, que en Piuray-Ccorimarca dónde las prácticas de CSA consisten principalmente de las terrazas de formación lenta instaladas en terreno de poco productividad. En Pacucha, las terrazas también producen un aumento significativo de la productividad del mano de obra. Se encontró que el producto marginal del terreno era más bajo en las fincas con terrazas, pero el producto marginal del mano de obra era más alto. En Piuray-Ccorimarca, se encontró el contrario: el producto marginal del terreno era más alto en las fincas con terrazas, pero el producto marginal del mano de obra era más bajo que en las fincas sin terrazas. Este efecto contrario se causó por las diferencias entre las dos áreas en la escasez de mercados de factores de producción. En Piuray-Ccorimarca, la tierra es más escasa pero más capital está disponible. La agricultura es más intensiva que se expresa por un input del mano de obra más grande en las actividades de cultivo y aplicación mayor de fertilizantes químicos. Esta sistema agricultura de alto input externo se define por el cultivo de papa, la escasez del terreno y los mercados mejor desarrollados en Piuray-Ccorimarca. Pacucha tiene que poder con faltas en el mercado de mano de obra y de productos agrícolas debido a su accesibilidad mala. A pesar del potencial de terrazas de aumentar la producción de maíz en Pacucha, los agricultores decidieron persistir la producción en el mismo nivel, mientras usando menos mano de obra. Esto resultó en una productividad del mano de obra de cultivo aumentada. Estos resultados muestran que las terrazas tienen el potencial para aumentar la producción agrícola y la productividad de factores, pero si esto es de interés a una familia campesina depende de los mercados de factores existentes. Cuando se promueven las prácticas de CSA, tiene que dar la atención al ambiente institucional.

La investigación demuestra que el atractivo de prácticas de CSA para una familia campesina en los Andes peruanos depende por sitio y familia. Cuanto más las familias dependen de la agricultura por su sustento y cuante más bajo sus costos de oportunidad de mano de obra, más ellos pueden beneficiar de CSA. Aunque la intervención externa por los programas orientados al CSA es el determinante lo más importante de adopción, se mostraron que los incentivos de los programas son menos importante que esperado. Los incentivos del mercado, por otro lado, parecen ser un importante determinante de adopción sustentable. Opponentes del uso de incentivos por las programas razonan que ellos aceleran el proceso de toma de decisiónes, produciendo una adopción inadmisible porque no se consideran condiciones importantes para la adopción sustentable. Sin embargo, también puede ser el caso que como estas condiciones para la adopción sustentable no puede crearse, los incentivos de las programas son importantes para lograr alguna adopción, como sin ellos, nada pasará. No obstante, para las prácticas de CSA de ser adoptados, es esencial para prestar atención al contexto institucional y constreñimientos del mercado. Como la situación difiere por región, deben descentralizarse las intervenciones de CSA. Si la meta principal de intervención de CSA es la conservación de recursos naturales, una intervención permanente por las autoridades locales puede ser considerada. Sin embargo, si el objetivo de intervención de CSA es mejorar los sustentos rurales a través de la producción agrícola aumentada, una comprensión buena de los mercados existentes es crucial.

Curriculum Vitae

Helena Posthumus was born on the 19th of February 1975, in Smallingerland, the Netherlands. She grew up in the rural area of Friesland, and attended the secondary school Ichthus College in Drachten. As a child, she was already studying the eroding effect of water, pouring down water on a sandpile in the sandpit in her parents' garden. She learned that water has enough force to cause mud flows that easily carry away toy cars and destroy houses made of sand.

In 1992 she came to Wageningen, to study Tropical Land Use at the Wageningen University. She specialized in Natural Resource Management. In 1996 she went to the Antenne Sahélienne in Burkina Faso, where she did research for her MSc-thesis on the impact of organic matter on soil stability. In 1997 she went to Benin, where she evaluated SWC practices of the programme RAMR for the Royal Tropical Institute (KIT), for her second MSc-thesis. In March 1998, she obtained her MSc-degree.

After doing volunteer work at the advisory service of the Foundation Agromisa, she was involved in a NOP-project with the research group of Erosion and Soil & Water Conservation at the Wageningen University, early 1999. She returned to Burkina Faso, to study the effect of hedgerow barriers on soil conservation and water balance at the Gampela research station of the Antenne Sahélienne. In October 1999 she was appointed as research assistant at the same research group.

In October 2000, Helena started her PhD, which was an interdisciplinary research project of the groups Erosion and Soil and Water Conservation (department of Environmental Sciences) and Development Economics (department of Social Sciences) of the Wageningen University. The research was executed in collaboration with the International Potato Centre (CIP) in Peru. She followed several postgraduate courses, and participated in international congresses. This thesis is the final outcome of her PhD-research.

Since July 2005, Helena works for the Institute of Environment and Water (IWE) at Cranfield University in Silsoe, United Kingdom. She is appointed as Research Officer, and is involved in several research projects. Her main task is to investigate the effects of policy on agriculture in the UK, with a special focus on farming practices that contribute to flood risk management, reduction of diffuse pollution and enhancement of biodiversity.

Helena can be contacted at: helenaposthumus@hotmail.com

PE&RC and Mansholt PhD Educational Statement Form

With the education activities listed below the PhD candidate has complied with the educational requirements set by the C.T. de Wit Graduate School for Production Ecology and Resource Conservation (PE&RC) and the educational requirements set by the Mansholt Graduate School, which comprises of a minimum total of 22 credits (= 32 ECTS)

Review of literature (4 credits)
- Soil and water conservation: adoption and incentives (2001)

Writing of project proposal (1 credit)
- Impact assessment for soil and water conservation and the role of incentives PE43 (2000)

Post-graduate courses (6 credits)
- Micro Economics Theory, NAKE / Tinbergen Institute (2000)
- Behavioural Economics, NAKE / Wageningen University (2001)
- Modelling Land Use Changes, University of Louvain (2002)

Deficiency, Refresh, Brush-up and General courses (6 credits)
- Advanced Econometrics, Wageningen University (2001)
- Quantitative Analysis of Development Policy, Wageningen University (2002)

PE&RC PhD discussion group (4 credits)
- Sustainable Land Use and Resource Management (2001-2004)

Seminars (1 credit)
- DEC Seminar Series (2001-2004)
- ESW Seminar Series "Advances in Sustainable Land Management" (2004)

International symposia, workshops and conferences (2 credits)
- International Symposium "Multi-Disciplinary Approaches towards Soil and Water Conservation Strategies", ZALF, Germany, May 11-13, 2001
- II Congreso Internacional de la Ciencia del Suelo "El Suelo: Manejo Integrado de Recursos Naturales", UNALM, Peru, 15-19 Noviembre 2004

Laboratory training and working visits (1 credit)
- International Potato Centre (CIP), Peru (2001)

Teaching activities
- Guest lectures ESW10504 Impact assessment of land and water management (2002-2004)
- Supervision ESW30106 Sustainable land use practical Spain (2004)
- Supervision MSc- and BSc-theses ESW and DEC students (2002-2004)