Resource Management in the Ecuadorian Andes:

An Evaluation of CARE's PROMUSTA Program

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Abstract

In recent years, development organizations have spent substantial resources on programs to reduce the problems associated with soil erosion. Many programs have focused on the use of incentives to induce conservation and have maintained a top-down approach to conservation. Quite often this is ineffective and farmers abandon conservation measures once incentives are withdrawn. In Ecuador, CARE International has offered an alternative approach that embeds conservation in the agricultural system. By offering agricultural diversification and intensification with a complementary program that enhances short-term benefits of conservation, CARE induces farmers to maintain sustainable practices. Using data from a sample of participant and non-participant Ecuadorian households, we show the success of the CARE approach. Participants in the CARE program are found to have high rates of adoption of conservation practices and to simultaneously change their agricultural system. Results indicate that with a strong extension service and a menu of adaptable technologies, conservation is enhanced when presented with complementary changes in agriculture.

Keywords: Ecuador, technology adoption, soil conservation, resource management

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1. Introduction

The problem of soil erosion, particularly in mountainous regions of the world, has received much attention in recent years. Governments, development agencies and non-governmental organizations have spent substantial resources on conservation programs designed to reduce the problems associated with erosion. Mountainous zones can have six distinct characteristics: inaccessibility, fragility, cultural and economic marginality, biological and socio-cultural diversity, the presence of niches and human adaptations (Yadav, 1991). These different yet interrelated characteristics make designing resource conservation programs particularly difficult. The tropical mountains of Ecuador are no exception. They are extremely heterogeneous, showing great variability over small distances with distinct rainfall patterns and ecozones in close proximity. Within the natural environment, the spatial arrangement of agriculture in the Ecuadorian Andes is characterized by a land use pattern resulting from land distribution of the agrarian reforms of the 1960s and 1970s. Small holder farmers cultivate mostly field and row crops located on the valley walls, while the remnants of large estates on the valley floors are dedicated mostly to dairy. This arrangement greatly enhances the erosion potential of vast areas of the inter-Andean valleys where most sierra agriculture takes place. Almost every discussion of environmental degradation in Ecuador includes erosion among the priority problems. One influential study placed 12% of the area of the country in the category of active or potentially active erosion, mostly concentrated in the sierra (de Noni and Trujillo 1986). The National Electrical Authority (INECEL) considers erosion from current or abandoned agricultural lands as the principal source of sedimentation in the hydroelectric reservoirs that supply nearly 70% of the electrical power in a country that experiences chronic shortages (INECEL 1992, Southgate and Macke 1989).

In fact, there is little understanding of the historical patterns of erosion, and there is a tendency to blame today's farmers or their parents for conditions that may have resulted simply from natural processes or prehistoric human activity. Nonetheless, impacts of erosion and its prevention have dominated much rural development thinking in Ecuador. Kaarhus (1993) defines three distinct phases. First, in the 1960s demographic pressure was blamed, and policies for colonization and industrialization frequently mentioned soil erosion among their justifications. Second, in the 1970s distortions in land tenancy were identified as the culprit. Finally, historical ecological reasons were identified as driving factors. They include: the drastic change in land tenancy during the colonial period, the abandonment of the ecological floor concept of agriculture for the Spanish/Moorish dryland-irrigated land concept of agriculture, the massive imposition of sheep raising, the use of off-farm labor, the imposition of mono-culture, and the division of land during the agrarian reform. It is in this context that current thinking about sustainable agriculture is being implemented in development projects throughout the country. In this study we examine the innovative experience of a large-scale, sustainable, agriculture-oriented, rural development program initiated by CARE International.

Programs designed to stem soil erosion have often focused on the use of incentives to induce farmers to conserve soil and water. The justification for these incentives is the perceived divergence between social and private returns to conservation, or failures in the credit market. There is growing evidence suggesting these programs do not always obtain the desired result (De la Briere, 1996; Obando and Montalván, 1994). In Ecuador, CARE International has tried an alternative approach. Rather than inducing conservation through incentives, CARE's PROMUSTA program promotes agricultural intensification and diversification to enhance the short-term benefits of conservation. In doing so, it embeds conservation in the agricultural system. The purpose of this paper is to evaluate the effectiveness of this model in inducing adoption of conservation techniques. As with any new technology, it is not expected that the conservation package offered by CARE will be immediately accepted. Information acquisition and household constraints may limit adoption of new technologies. In evaluating the CARE technical package, we consider the factors that influence adoption and the intensity of adoption.

The remainder of the paper is divided into eight sections. Section 2 gives a brief history of CARE's PROMUSTA project, its objectives, and how it operated. In section 3, we describe how data were collected. Section 4 provides information on the communities sampled and households that live in those communities. Participant and non-participant households are compared. In section 5, background information on soil and water conservation is presented. In section 6, we examine adoption from the parcel-level and try to explain factors that influence the adoption decision. In section 7, the household's perspective and the intensity of adoption of appropriate agricultural practices is examined. Section 8 briefly examines the impact of the PROMUSTA program. Conclusions and suggestions for further research are presented in section 9.

2. CARE's PROMUSTA project

The PROMUSTA[3] project was initiated by CARE International in 1988 in conjunction with the Ecuadorian Ministry of Agriculture and Livestock and other government bodies at the state and local level.[4] The project initially focused on promoting soil conservation, but eventually became more encompassing, by including natural resource management in general. Ultimately, as the project progressed and developed, it adopted a wholistic approach that integrated natural resource management with components for strengthening institutions, training and extension, agricultural intensification, crop diversification, pastures and livestock management, forestry and agroforestry, and water management. The menu of technological options developed by PROMUSTA offered diverse possibilities for farmers. Technologies were adapted by extension agents and farmers to meet local conditions. The formal objective of the project was the promotion of better resource management by small farmers (*minifundistas*) in the Ecuadorian sierra through the adoption and adaptation of sustainable land use practices with the ultimate objective to improve the quality of life for farmers in the short- and long term.[5]

Executing this project required selecting communities to work within each region. Although the project planned work in seven mountainous provinces of the Ecuadorian Andes, work began slowly in each region. Therefore, not all communities entered the PROMUSTA program at once. Administrative units were organized by region (North, Central and South) and by area, which generally corresponded to provinces. Local conditions often dictated the focus of the area. The initial phase of development in each area (phase 1) included a pre-diagnostic study designed to obtain general information about potential communities in each province. Once possible sites were selected, communities were specifically selected based on the following criteria:

1. Interest by both men and women in the project;
2. Limited migration (specifically, not greater than 60%);
3. A community economy based on agriculture, forestry and animals;
4. A community located in an important watershed;
5. No other similar institutes working in the community; and
6. Superior community organization.

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[3] PROMUSTA is an acronym for Proyecto Manejo del Uso Sostenible de Tierras Andinas which translates as Project for the Sustainable Use of Andean Lands.

[4] PROMUSTA was a continuation and expansion of previous projects that also focused on resource management. Some of the communities in the PROMUSTA program began working with CARE as early as 1985, prior to the initiation of PROMUSTA.

[5] For information on PROMUSTA see PROMUSTA, “Manual de Seguimiento, Reporte y Evaluacion Convenio MAGSuelos-CARE” (no date).

Map 1 identifies sites that represent the general locations of the 193 communities that worked or currently work with PROMUSTA. The communities are located from the northern to southern Ecuadorian Andes and represent a variety of climatic, topographical, cultural and economic conditions.

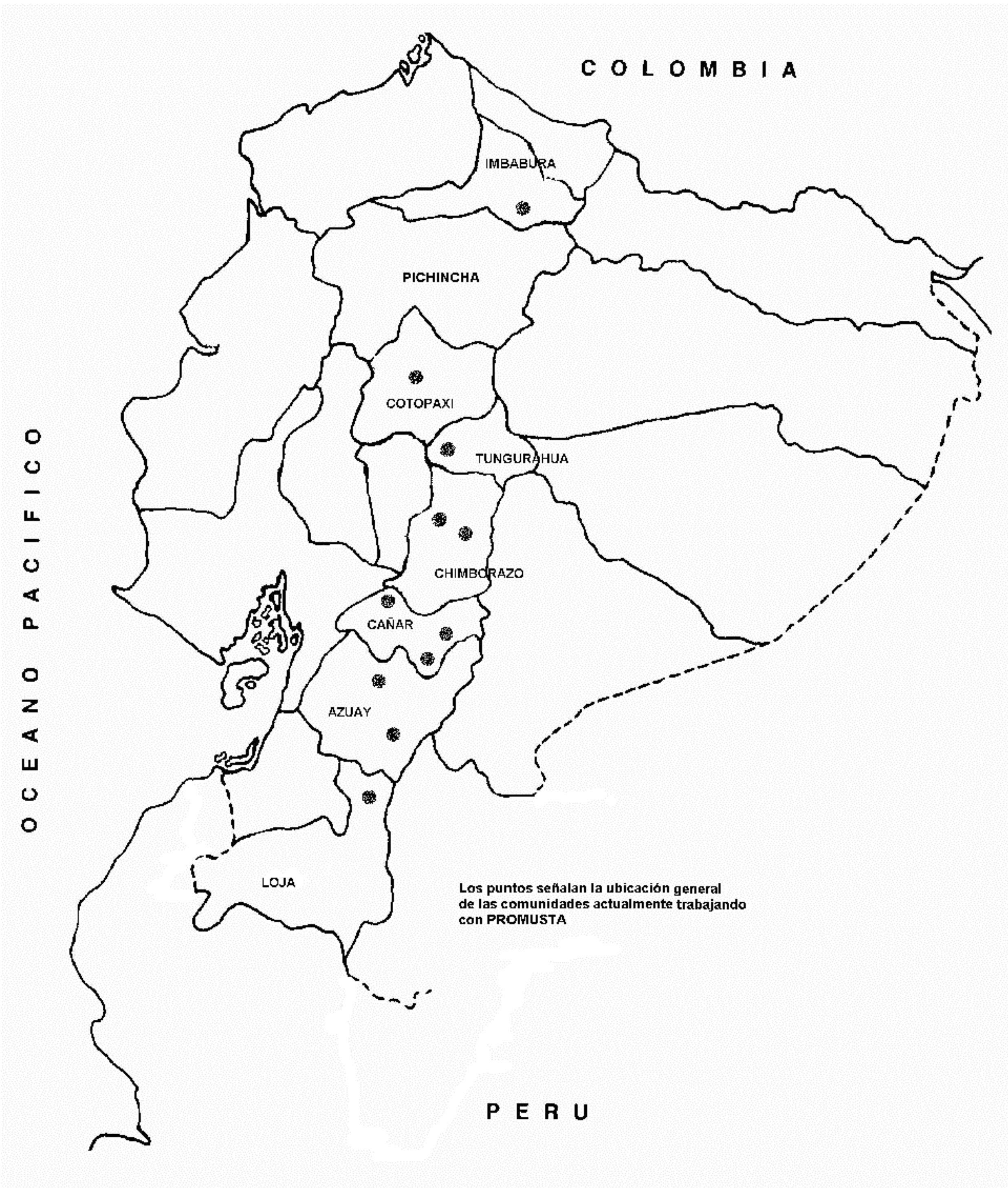
After the communities were identified in the selection phase, a diagnosis of the community and a planning of actions occurred (phase 2). In this phase, PROMUSTA representatives and community members discussed the needs and interests of the community with respect to resource conservation. Discussions established the responsibilities and contributions of PROMUSTA and the community participants. In each community, farmer-promoters were selected to oversee project activities. These farmer-promoters would play an important role in facilitating activities between PROMUSTA and the community. By the end of this phase, an action plan for the community was established.

The third phase, training and execution, involved executing the plan developed in phase 2 and training the farmers. Training was done through field days, workshops, group discussions, demonstration plots, and trips to farmers' fields in other communities. The project used a participative strategy that encouraged discussions of experiences and analysis of actions taken. During this phase, the farmer-promoters facilitated activities, stimulated participation in conservation practices and, quite often, used their land for demonstration plots.

After initial training and execution of the plan, the community entered a phase of development defined as consolidation and adoption (phase 4). During this stage farmer-promoters and project participants engaged in active participation and movement towards improved management of natural resources, with extensive adoption of new technologies. By this time, a significant increase in knowledge about natural resource management was expected. Participatory activities, planning, and evaluation of activities continued to occur, and extension agents visited the community regularly.

Finally, once the community reached a level of maturity, and had learned to continue planning and executing conservation without external assistance, the community graduated from the project (phase 5). This decision was made in consultation with community participants. Of course, these phases represent the ideal stages of development for a community. In some circumstances, communities lacked interest in continuing work or failed to progress sufficiently. In those cases, PROMUSTA quit the community.

Map 1. PROMUSTA communities.



3. Survey design

In 1996, the International Potato Center (CIP), with the active participation of PROMUSTA staff and funding from CONDESAN (Consortium for the Sustainable Development of the Andean Ecoregion), began an evaluation of the PROMUSTA program. The objective of the study was to determine CARE's success in promoting the adoption of better resource management and to identify conditions under which CARE had been most successful. The survey questionnaire was developed based on an Ecuador-focused literature review (Crissman and Espinosa 1996) and the informal hypotheses of the PROMUSTA technical staff. Using PROMUSTA extension agents as enumerators, CIP administered a household-level survey from June to September 1996.[6] Selecting the sample for the survey required first, selection of communities for the sample and then, within each community, selection of participant and non-participant households to be surveyed.

Communities for the sample were selected using a number of criteria, rather than randomly, to ensure the communities represented important differences across the PROMUSTA project. The criteria used were exogenous — i.e., not a product of participation — and included:

1. Location within the region;
2. Status in the PROMUSTA program (phase);
3. Distance to urban centers;
4. Altitude;
5. Soil quality/potential; and
6. Presence of *paramo*.[7]

In practice, communities were selected by area, which corresponds to the administrative unit of PROMUSTA. In each area, CIP and PROMUSTA personnel (leaders and extension agents) met to discuss important criteria for selecting communities in that region. Based on these criteria, a set of potential communities was selected and a few communities were randomly chosen from this set. Table 1 notes the total number of communities in the province, the number of communities selected, and the criteria used for the region. In total, 44 of the 193 communities in the PROMUSTA program were selected.

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[6] Enumerators never conducted surveys in communities where they worked as extension agents.

[7] *Paramo* refers to the type of high altitude grassland found in the Ecuadorian Andes. In many communities, farmers have been encroaching on this land.

Table 1. Survey design.

	Province	PROMUSTA communities	Selected communities	Selection criteria	Surveyed Households
North	Imbabura	15	4	Location, soil quality	61
⇓	Cotopaxi	33	6	Location, distance to urban center, PROMUSTA status	63
⇓	Tunguragua	34	8	Location, soil quality, altitude, PROMUSTA status	112
⇓	Chimborazo	28	6	Location, soil quality, presence of paramo, PROMUSTA status	88
⇓	Cañar	35	6	Location, distance to urban center, PROMUSTA status	68
⇓	Azuay	21	8	Location, soil quality	83
South	Loja	27	6	Location, soil quality, altitude, PROMUSTA status	55
	Total	193	44	Location, soil quality, altitude, distance to urban center, presence of paramo, PROMUSTA status	530

Within each community, households that participated in the project and households that did not participate were surveyed. Using lists of community members and their participation status, households were randomly selected to be interviewed for the survey. When a selected household was not available for an interview, then the nearest household with the same participation status was used to replace the missing household. Within the 44 communities, 530 households were surveyed.

Recognizing the importance of community factors in adoption of the PROMUSTA package of technologies, we also conducted a community-level survey. Information on each community was gathered from the extension agents working within the communities and from discussions with key informants in each community.

4. The data

The communities selected in the sample were chosen to represent the diversity of communities within the PROMUSTA project. Communities are important in Ecuador and the Andean region in general. They are the lowest organizational unit and farmers depend on community organization for assistance. Table 2 shows some characteristics of the 44 communities in the sample. CARE initiated work on resource conservation in

Table 2. Community characteristics (Number of communities = 44).

	Mean	*Stan. Dev*	*Minimum*	*Maximum*
CARE-PROMUSTA				
Year PROMUSTA project began	1991.4	3.0	1985	1996
Phase 3: Training-execution (%)	4.5%	-	-	-
Phase 4: Consolidation and adoption (%)	56.8%	-	-	-
Phase 5: Graduation (%)	22.7%	-	-	-
Termination (%)	15.9%	-	-	-
PROMUSTA participation (ave. %)	52.2%	29.1%	7.5%	100.0%
Income/assets				
Land ownership (ave. hectares)	1.1	1.3	0.8	6.3
Value of large animals (ave. US$)	1627	979	574	4572
Poverty (1-10, 1=very poor)	4.6	1.4	2.0	8.0
Education (ave. years)	4.0	1.3	1.8	7.4
Outside income (ave. %)	32.0%	16.0%	7.0%	64.3%
Institutions				
Organization (ave. membership)	1.3	0.4	0.4	2.0
Organization index (1-5, 1=very organized)	2.5	0.8	1.0	4.0
Indigenous (ave. %)	54.2%	41.3%	0.0%	100.0%
Land charactersitics				
Moisture (1-10, 1=deficient moisture)	4.6	1.4	2.0	7.0
Soil potential (1-10, 1=low potential)	4.9	1.7	2.0	9.0
Population density (households/ha)	0.70	0.97	0.03	5.00
Comunal land (ave. %)	29.2%	34.3%	0.0%	92.3%
Rain (mm./year)	629	193	280	1200
Infrastructure access				
Farmers with irrigation (ave. %)	13.6%	20.8%	0.0%	90.0%
Distance: major fair (km)	17.6	13.5	3.0	70.0
Distance: paved road (km)	18.5	20.4	0.5	115.0
Distance: health clinic (km)	10.8	17.1	0.0	80.0
Distance: city > 50,000 people (km)	51.2	36.4	4.0	155.0

some communities as early as 1985. Four of the 44 (9%) communities began interacting with CARE in that year. In 1992, the PROMUSTA program went through an external review, which led to shifts in program emphasis and an expansion of areas of action. Just under half (43%) of the communities selected were part of PROMUSTA before this review and the remainder (57%) began work with PROMUSTA after the review. Most of these communities entered the program in 1993 or 1994, although one community began in 1995 and one in 1996. All of the communities in the sample had completed phase 2 (planning of actions) by the time of the survey. Each community was then classified as being in one of the following groups: 1) phase 3: training and execution, 2) phase 4: consolidation and adoption, 3) phase 5: graduation, and 4) termination. Termination of the project could occur during any phase and resulted from a lack of interest by participants or a failure to progress. Most of the sampled communities (56.8%) were in the consolidation and adoption stage. Of those communities no longer part of the project, 22.7% graduated from the program and 15.9% were terminated. Participation in PROMUSTA was voluntary and in only 5 communities (11.4%) did all members of the community participate. On average about half of community members participated (52.2%), with participation ranging from 7.5% to 100% of community members.

CARE's mandate is to assist the poor. National poverty estimates show 35% of the total population and 47% of the rural population is under the poverty line (World Bank, 1997). Since PROMUSTA works with marginal farmers on hillsides and poverty tends to be concentrated in these areas, it is likely that the majority of farmers in the sample earned incomes below the poverty line. Even though these farmers may be all classified as poor, within the PROMUSTA communities there was significant variation in a number of characteristics. Average land ownership for the community was as low as 0.8 ha and as high as 6.3. Extension agents were asked to rate the level of poverty in each community on a scale of 1 to 10 (1=very poor). While 57% were given a score of 4 or 5, 20% were below 4 and 23% were above 5. The average level of education was 4 years, but in some communities the average education level was as low as 1.8 years and in some as high as 7.4 years. Off-farm income represented as little as 7%, and as much as 64%, of total household income.

Soil conservation potential depends to a large extent on soil characteristics, water availability and the population density. Extension agents were asked to evaluate community land on the basis of soil moisture (1= deficient moisture) and soil potential (1=low potential). Soil moisture ratings ranged from 2 to 7 with 31% rated at 4, 22% below 4 and approximately 15% each rated 5, 6 and 7. Soil potential ratings tended to be a bit higher with 27% rated at 6. However, 27% were rated as low as 2 or 3. Although interpreting such numbers is difficult due to their qualitative nature, the numbers do suggest that the potential for soil conservation may vary across communities. Average annual rainfall was 629 mm, with the driest community receiving

280 mm/year and the wettest 1200 mm/year.[8] Approximately one-third of the communities received 500 mm/year or less of rainfall, one-third between 500 and 750 mm/year and one-third over 750 mm/year. Population density, defined as the number of households per hectare of land in the community, also varied substantially, from a rather disperse 0.03 households per hectare of land in the community to 5 households per hectare of land. Only 2 communities (4.5%) had more than 2 households per hectare and only 8 communities (18.2%) had more than 1 household per hectare.

Adoption of soil conservation within a community depends on the institutional structure. Information on conservation flows more easily in organized or homogenous communities, and extension agents also find it easier to work in well-organized communities. Individual membership in organizations varied from a community average of 0.4 organizational affiliations to 2 organizational affiliations with an average membership of 1.3. Extension agents were asked to evaluate the organizational level of the community on a scale of 1 to 5, with 1 being very well organized and 5 poorly organized. Fifty-two percent of communities were described as very well or well organized while 41% were considered average in organization. Only 7% were considered poorly organized. The predominance of well-organized communities was expected, given the community selection criteria of PROMUSTA. Those poorly organized communities were present either as result of a misdiagnosis during the community selection process or deterioration of organizational conditions after enrollment. Half of the communities were ethnically homogeneous with 32% reported as completely indigenous and 18% as solely mestizo. The remaining communities were ethnically mixed with an average 45% indigenous.

Part of the PROMUSTA technology package includes agricultural intensification and diversification, which depends in part on the availability of infrastructure and access to markets. Table 2 presents a number of infrastructure variables by community. On average, 13.6% of farmers in a community had access to irrigation. However, 25 communities (57%) had no irrigation infrastructure. Of the communities that did have irrigation (43%), 32% of farmers in those communities had access to irrigation. Distance to fairs (weekly local markets), paved roads, health clinics and cities of over 50,000 people are measures of market access and development (less infrastructure generally implies less development). These variables differ widely across the communities.

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8 Rainfall data are estimates obtained from individuals knowledgeable about the community. They were not obtained using weather station data or any precise measuring instruments.

In summary, Table 2 indicates there was significant variability across the communities in our sample. This is not surprising for two reasons. First, as noted in section 3, the communities in the study were chosen to reflect particular characteristics. Second, the Andes are culturally, geographically and economically diverse. By working in communities from the Southern to Northern Ecuadorian Andes, CARE has had to deal with tremendous difference in communities, making introduction of new technologies difficult.

Table 3 reports information on the 530 sampled households. The average household size was 5.1 members. A member of a household was defined as anyone

Table 3. Participant versus non-participant households.

	Total	***Non-part.***	***Participant***	***Test***	
Number of observations	530	117	413	-	
% of total obs.	100.0%	22.1%	77.9%	-	
Household variables					
Human capital assets					
Household members	5.1	4.6	5.2	-2.76	***
Male labor/ha.	8.2	7.8	8.3	-0.26	
Female labor/ha.	8.6	7.9	8.8	-0.44	
Age of household head	42.7	41.8	42.9	-0.74	
Education level (household ave.years)	3.6	3.4	3.6	-0.73	
Income source					
Months working off-farm (head)	4.0	4.6	3.9	1.45	
Income from off-farm work (%)	32.4%	38.1%	30.8%	2.31%	**
Physical assets					
Land owned (hectares)	1.0	0.9	1.1	-0.37	
Land operated (hectares)	1.1	1.0	1.1	-0.40	
Number of parcels	1.5	1.4	1.5	-2.39	**
Slope of steepest parcel† (%)	26.8	23.7	27.7	-2.05	**
Altitude of highest parcel (meters)	3090	3013	3097	-0.88	
Value of large animals owned (US$)‡	1548	1309	1615	-1.73	*
Chickens owned	6.5	6.7	6.4	0.27	
Guinea pig owned	17.6	14.5	18.5	-1.89	*
Rabbits owned	1.5	1.2	1.6	-0.57	
Institutional assets					
Organization affiliation (no.)	1.3	0.9	1.4	-6.84	***
Was/is director of organization (%)	51.6%	23.1%	59.7%	48.89%	***
Indigenous (%)	62.0%	65.8%	60.9%	0.94%	

Test of difference between non-participant and participant households -- t-stats and chi-squared as appropriate. *= significant at 90%, **= significant at 95%, ***=significant at 99% level .
† Data on slope is missing for four households
‡ = cows, horses, mules, pigs, sheep, goats and llamas. Data is missing for one household.

who lived in that household regardless of the relationships; it may include grandparents, children, cousins, aunts and uncles and non-family members. A household's labor may be very important for soil conservation since conservation measures often require significant labor expenditure. Household labor was defined as including any household member over the age of 14. We distinguished male and female labor, since each is often used for different agricultural activities, and we divided labor by operated land area to determine labor availability per unit of land. On average each household had 8.2 male labor units per hectare and 8.6 female labor units per hectare. The higher number of females can be explained by the permanent migration of male labor. The age of the head of the household, usually the eldest male, represents the life cycle stage of the household and the experience of the primary decision-maker. The average household head was 43 years old. Skill level within the household is measured by years of education. On average, household members had 3.6 years of education.

One-third of household income came from off-farm sources. This was apparent in the percent of reported off-farm income (32.4%) and the average months per year the head of household works off-farm (4 months). This suggests that for extensive periods of the year, much of household labor is not available for farm work. Farmers on average owned only 1.0 hectare of land and operated slightly more (1.1 hectares) through rental, loan or sharecropping contracts. Seven percent of farmers surveyed owned no land and 79% owned 1.0 hectare or less. Only 5% of farmers owned 4 or more hectares. Farmers in the sample did not operate many parcels; the average number was 1.5.[9] Sixty-two percent of farmers worked only one parcel, 27% worked 2 parcels and the remainder (11%) worked on 3 to 6 parcels.

Livestock, particularly large livestock (cows, horses, mules, pigs, sheep, goats and llamas), can be a source of savings and production for the household. Using prices from a provincial fair in October 1997, we approximated the value of large livestock owned. On average the value of a farmer's livestock was US$1,545. However, nearly half of farmers owned less than US$1,000 worth of livestock.

Institutional assets can assist in the facilitation of information and the actual adoption of a new technology and households in the CARE communities are well affiliated. Farmers were members in 1.3 organizations on average and 51.6% of farmers noted they were at one time director of an organization.[10] Again, this degree of activism was to be expected given PROMUSTA's community selection criteria based on superior community organization.

Both participating and non-participating households were considered in the study. The second and third columns of Table 3 present data on these two groups of

[9] Farmers in Ecuador refer to their fields as *parcelas* from which we use the English "parcel". So, here a parcel is a contiguous piece of land with one or more crops.

[10] The term organization refers to permanent affiliations such as farmers' associations. As a temporary program, PROMUSTA is not considered an organization.

households. Farmers chose whether or not to participate in the PROMUSTA program. When evaluating a program there is always the potential for selectivity bias. Those who belonged to the PROMUSTA program may have been more likely to adopt conservation packages anyway even if the program had not been implemented. The benefits of the program are measured by the amount of adoption that occurred beyond what would have occurred if the program had not been implemented. Of course, we do not know what would have happened if the program had not been implemented. Separating the effects of the program and the self-selection of participants can be difficult. One way to determine selectivity bias is to see if there is any systematic difference between participating and non-participating households. Tests of difference between households using t-tests for averages and chi-squared tests for discrete variables are reported in column four of Table 3.

From Table 3, note that households with more members (4.6 versus 5.2) were more likely to participate. This could be due to labor availability, but though participating households tended to have more labor per hectare, neither male nor female labor per hectare of operated land was found to be significant. Farmers with more off-farm income (38.1% versus 30.8%) tended not to participate. Farmers with fewer workers on the farm may be less likely to have time or the labor resources to participate. Participants tended to have slightly more parcels than non-participants (1.5 versus 1.4), steeper parcels (27.7 versus 23.7%), more livestock assets ($1,611 versus $1,309) and more guinea pigs[11] (18.5 versus 14.5). Participants were also more likely to be members of an organization (1.4 versus 0.9) and to have been a director of an organization (59.7% versus 23.1%).

While these numbers do indicate some differences between participants, it is difficult to determine what is endogenous (i.e., a result of participation) and the source of causation. For example, the PROMUSTA program has promoted the raising of guinea pigs, so it is not surprising that participants own more of these. A better method of examining participation is the use of a probit regression. A probit on participation estimates the probability of a household participating in the PROMUSTA program given a number of household characteristics. It is important to choose the determinants of participation based on *ex ante* beliefs about why households participate. Table 4 reports the results of the probit on participation. Only the value of large animals, operation on a steep slope, and institutional variables were significant. The marginal effects of each variable are reported for the average farmer — that is, the farmer that

[11] In the Andes, it is very common for households to raise guinea pigs for sale or home consumption. The guinea pigs are often kept in stalls within the house or in a shed.

has average characteristics. The results indicate that farmers with steeper fields were more likely to participate in the PROMUSTA program; specifically, for the average farmer, a 10% increase in slope led to a 2.9% increase in the probability of participation. Organizational membership was shown to increase the probability of participation by nearly 15%. Present or past directorship of an organization increased participation by the average farmer by 17%. Indigenous households were 10.0% less likely to participate. In summary, these results indicate that the difference between participants and non-participants is that participants tended to have more animal assets, a field susceptible to erosion (measured by slope), were interested and receptive to organizations and were less likely to be indigenous. Along with the poor predictive power of the probit, these results indicate that participant and non-participant households are not dramatically different. This suggests that technologies adopted by participant households may be equally useful for non-participants.

Table 4. Probit of PROMUSTA participation.

	Marginal effects	***z-statistic***	
Human capital assets			
Male labor/ha	-0.0003	-0.19	
Female labor/ha	0.0017	1.07	
Age of head	0.0002	0.13	
Education level	-0.0066	-0.71	
Off-farm income	-0.0004	-0.62	
Physical assets			
Land owned	-0.0078	-1.50	
Value of animal assets	0.00002	1.66	*
Slope of steepest parcel	0.0029	2.88	***
Altitude of highest parcel	0.0001	1.02	
Institutional assets			
Organization affiliation	0.1481	4.88	***
Was/is director of organization†	0.1817	4.64	***
Indigenous†	-0.1001	-2.34	**
Constant	-	0.51	

†For dummy variables, marginal effect is a discrete change from 0 to 1.
*= significant at 90%, **= significant at 95%, ***=significant at 99% level.
Five variables were dropped due to missing data.

	Predicted participant	Predicted non-part.
Actual participant	387	22
Actual non-participant	94	22
Percent correct	80.5%	50.0%
Total percent correct	77.9%	

5. Perspectives on resource conservation

The analysis of resource degradation and conservation can be examined from a societal or farm perspective (Lutz, Pagiola and Reiche, 1994). Whether defining society as an entire country, a region or a watershed, from a social perspective all costs of degradation and benefits of conservation need to be included. This encompasses everything from reduced agricultural productivity to the siltation of rivers and reservoirs caused by soil movement. The evaluation of costs and benefits should be done using social rather than market prices since the latter may be distorted. The optimal level of conservation reflects the objectives of the society. The farm perspective represents the costs and benefits of degradation and conservation on the farm, without concern for off-farm effects and taking market prices as given. Conservation measures are taken on the basis of short-run costs and the long-term (discounted) benefits. Examining conservation at the farm level is appealing since agriculture tends to be the source of much degradation and it is the farmers themselves that must choose to adopt conservation measures. In this paper, we focus entirely on farm-level conservation.

Another issue to address is the conceptual treatment of degradation and conservation in economic analysis. In their review of the socio-economic literature on degradation and conservation, Thampapillai and Anderson (1994) identify three categories of analysis: 1) soil conservation as an input in production; 2) topsoil as a renewable or non-renewable resource; and 3) degradation in the framework of common property resources. Adoption of conservation practices is directly related to the effects of conservation on productivity, output and income. Presumably, adoption will only occur if and when the net income benefits are positive. Conservation is an input in production and falls into the first category. Thus, throughout our analysis we maintain the perspective of conservation as an input in production.

By focusing on farm households and examining the adoption of conservation measures, we implicitly assume that resource degradation is a problem and that the social benefits are sufficiently high to justify outside intervention. Adoption of PROMUSTA recommendations is assumed desirable. Our purpose is not to evaluate the household net benefits or total net benefits of the PROMUSTA project. We examine the determinants of adoption at the parcel and household level with the hope of shedding light on the factors that contribute to adoption. Data was collected with this focus in mind and the impact of PROMUSTA can only be imputed from household adoption. This assumes that adoption only occurs when households perceive a net benefit.

Technology adoption can be examined at the individual and aggregate level. For an individual, adoption is the mental process an individual undergoes from first hearing of an innovation to adopting it (Rogers, 1962). Aggregate adoption is the process by which technology diffuses through a community, region or country. Although aggregate adoption of the PROMUSTA package is of interest, we will primarily focus on individual adoption, examining adoption on each parcel and the intensity of adoption at the household level.

When analyzing adoption, a consideration of the household, in addition to the parcel, is critical for proper evaluation of the adoption decision. While parcel characteristics, such as slope, topography, soil type, rain distribution and irrigation access may be important in the adoption decision, it is the household that is the decision making entity. Decisions to adopt depend on household income opportunities, income risk and risk aversion, labor availability, credit access, asset position, farm size, land tenure and human capital. The variety of constraints and the presence of market failures make the household incapable of separating production and consumption decisions and justify a household-level approach (Singh, Squire and Strauss, 1986). Below we evaluate adoption at the parcel level to examine the adoption of certain technologies, but use the household as the unit of analysis to determine factors that influence overall adoption.

Although the PROMUSTA package contains a number of components, resource conservation is clearly a focus of the program. Adoption of conservation measures is related to farmers' perceptions about erosion. Farmers were asked questions about erosion in the survey. Since the questions were asked after the PROMUSTA program was initiated, it is difficult to determine if farmers' perceptions have been greatly altered through interaction with CARE extension agents. It would be surprising if this were not the case.

When examining the farmers' perceptions of soil erosion (Table 5) this should be kept in mind. Soil loss was noted to be a problem for 80.2% of households, with more participating households considering erosion a problem than non-participants. Erosion can be caused by a number of factors, including water management, wind, slope, human activities and natural causes. PROMUSTA participants were more likely to attribute soil losses to water, management, slope and human activities. Non-participants were more likely to not know or to attribute soil loss in general to "natural causes". This suggests participants had a better understanding of the causes of erosion.

Table 5. Farmers' perceptions of soil conservation.

	Total	*Non-part.*	*Participant*	*Test*	
Number of observations	530	117	413	-	
% of total obs.	100.0%	22.1%	77.9%	-	
Problems with soil loss (% noting)	80.2%	74.4%	81.9%	3.26	*
Cause of soil loss (% noting the following)					
Water	71.6%	60.9%	74.6%	8.72	***
Management	67.4%	53.9%	71.3%	12.59	***
Wind	44.6%	39.3%	46.1%	1.71	
Slope	29.4%	17.1%	32.9%	10.90	***
Human activities	23.4%	16.2%	25.4%	4.24	**
Natural causes	14.1%	17.1%	13.3%	0.09	
Don't know	4.3%	7.7%	3.4%	4.09	**

In the survey, participants were asked whether they had taken actions to counter soil loss prior to entry into PROMUSTA. Eighteen percent of participants reported taking some action. Non-participants were asked if they had ever taken action to counter soil loss before the time of the survey and 44.4% reported doing so. The survey did not ask before and after questions to non-participants. However, supposing that non-participants and participants possessed a similar level knowledge of soil conservation management practices prior to PROMUSTA, then there is ample evidence of spillover effects from PROMUSTA to non-participants. That is, non-participants taking actions to counter soil loss increased from 18% to 44%.

6. Parcel-level resource management

The objective of a conservation program is to induce farmers to manage their parcels in a manner that limits the degradation of the land. Advocates of soil conservation often argue that without external incentives, farmers will not invest in conservation or, at least, an insufficient number of farmers will invest. The primary motivation for incentives is that the benefits of conservation do not accrue solely to farmers (net social benefits exceed net private benefits) and to reach a desirable social outcome it is necessary to subsidize conservation activities. Another rationale for incentives is that credit markets do not function properly making soil conservation difficult to undertake, since this often requires high immediate costs with the promise of future benefits. In this context, failure to adopt conservation measures does not mean farmers do not perceive benefits to conservation, but are liquidity constrained and cannot invest. Theoretically, incentives are designed to overcome the problems of divergence between social and private benefits or credit constraints. External incentives include credit provision for investing in conservation measures, and various forms of subsidies, such as free inputs, payment for labor used for conservation, or even direct construction of conservation structure. The logic of these incentive programs is that by reducing the short-run costs of conservation, farmers are induced to conserve for long-term benefits.

The problem with programs offering incentives is that the conservation programs they promote are often not maintained. In her analysis of adoption and maintenance of the Plan Sierra conservation program in the Dominican Republic, de la Briere (1996) notes that of the 190 program participants surveyed, 91% adopted some conservation practices while in the program. At the time of the survey however, 27% of adopters had completely abandoned the conservation practices. De la Breire shows that termination of subsidies leads to an immediate increase in abandonment of conservation practices. Some farmers therefore participate only to receive subsidies. In another study of the Dominican Republic, Carrasco and Witter[12] (1991) report a 90% adoption rate of conservation practices in the MARENA program while subsidies were still being offered. Five years after subsidies had ended, only 53% of adopting farmers still maintained the practices. Obando and Montalvan (1994) note a similar phenomenon in the Lake Xolotlan region of Nicaragua. In that region, conservation measures were constructed at no cost to the farmers in order to limit flooding in Managua. Many of the structures were abandoned or destroyed because they interfered with common agricultural practices.

Abandonment may be motivated by the fact that maintenance costs of structures exceed the benefits of conservation, or there are little or no benefits to conservation. Another, more likely reason, noted in the Nicaragua case above, is that conservation interferes with current agricultural practices and lowers short-run agricultural output and profit. For example, terraces lower the surface area available for planting, and make tractor and oxen use more difficult. This is particularly a problem when an outside expert, rather than the farmer himself, determines the location of terraces. Government or NGO officials may erect terraces where they will best conserve soil and water, but not where they are most conducive to agricultural production. Conservation decisions thus become not solely a matter of comparing the costs of conservation measures and the future benefits of reduce degradation, but include the effects on current agricultural

[12] Cited in Hernandez (1994).

production. Murray (1994) notes the interaction between conservation and current production when he writes:

> Enthusiasm for soil conservation is high only when the increments in productivity likely to come from new land use practices rise above a certain threshold. Soil conservation by itself rarely creates or sustains such threshold level of increments. Rather, soil conservation is generally adopted in conjunction with, and response to, other technological or economic shifts… Farmers are more open to soil conservation measures when these measures are not presented as the principal element in the project, but rather as secondary, ancillary items in a menu featuring innovations with impressive short-term, income generating potential.

Along similar lines, Barbier (1990) in his study of soil conservation in Java notes that switching from a corn or cassava to higher valued crops increased the returns to terracing and thus increases adoption of terraces.

To understand soil conservation, we need to understand the costs of investing in conservation measures, the long-term benefits of reduced soil loss, and the effects of conservation on agricultural practices. All these will be factors in the decision to adopt. One important consideration is the relationship between conservation and agricultural practices. If conservation is complementary to agricultural production — i.e., enhances the profitability of agriculture — then adoption is much more likely. If conservation is a substitute for agriculture — i.e., land is taken away from agriculture for conservation — then adoption is less likely. As Murray (1994) notes, farmers are more open to conservation if it is part of a menu of innovations. If that menu presents options that promote the complementarity of agriculture and conservation then adoption is more likely. This is precisely the PROMUSTA model. The program is not simply a soil conservation program, but a complete resource management program that offers conservation as one component of a general change in agricultural production. Incentives are limited to provision of seeds, plants and inputs and not direct payment for conservation. One objective of our data analysis was to test whether this model is effective.

6.1 Parcel-level adoption

To begin the analysis, we look at data on parcel-level adoption. Recall that on average, households owned 1.5 parcels. As can be seen in Table 6, the 530 households in the survey operated 774 parcels. On 536 (68.2%) of the parcels some new technology had been adopted. Adoption was not necessarily full adoption, but any parcel with technology adoption or, equivalently, an intensity of adoption greater than zero. On average, farmers operated their parcels 15.7 years. Although farmers' fields were on average 517 meters from their houses, 60% were next to or within 30 meters of the house. Only 20% of households operated a parcel more than 1000 meters away.

Table 6. Parcel characteristics.

	Total	No adoption	Adoption	Test
Number of parcels	774	246	528	-
% of total	100.0%	31.8%	68.2%	-
Years used	15.7	16.3	15.4	0.97
Distance to the house (meters)	517	586	485	1.08
Ownership	92.5%	95.2%	91.2%	3.56 **
Hold title to land	60.2%	61.8%	59.5%	0.38
Area (hectares)	0.76	0.71	0.78	-0.35
Altitude (meters)	3085	3048	3099	-1.76 *
Slope (%)	24.1	22.5	24.9	-1.73 *
Top soil condition†				
Deep	30.2%	22.8%	33.6%	14.95 ***
Medium	53.2%	54.4%	52.6%	
Shallow	16.7%	22.8%	13.8%	
Soil type				
Loam-clay	53.3%	50.0%	54.9%	1.61
Loam-sand	15.4%	17.6%	14.4%	1.37
Silt-clay	8.8%	5.2%	10.5%	5.86 **
Sand	1.3%	0.8%	1.5%	0.65
Loam-sand	5.0%	0.8%	6.9%	13.47 ***
Loam-silt	3.7%	6.0%	2.6%	5.51 **
Clay	10.2%	15.2%	7.8%	10.11 ***
Other	1.5%	2.0%	1.3%	0.54

† test is for joint significance

Parcels on which adoption occurred tended to be closer to the house, although there was not a significant difference. Surprisingly, only 91.2% of adopters owned their land compared to 95.2% of non-adopters. Even when comparing farmers with and without ownership papers, we find those with papers are slightly (though not significantly) less likely to adopt any technology. This runs against the conventional wisdom that adoption of conservation measures is less likely to occur on parcels that are not owned. One explanation is that surveyed farmers feel tenancy (even without title) is secure, and long-term investment is then justifiable. The agricultural land titling agency in Ecuador estimates that 40 percent of agricultural land in the sierra provinces is without title dating from the reforms of the 1960s and 1970s (El Comercio, 1998). Farmers have long established *de facto* rights and do not feel threatened. Another possibility is that the short-term benefits of the technology adoption are sufficiently high to outweigh concerns about tenancy status. The size of a parcel is positively, although not significantly, related to adoption. Adoption was less likely to occur on smaller parcels. While the adoption rate for all parcels was 68.2%, the adoption rate was 61.8% for parcels under 500 square meters, 51.9% for parcels under 250 square meters, and 30% for parcels under 100 square meters. Parcels that were higher and steeper were much more likely to have some level of adoption. On average, parcels with some adoption tended to be 50 meters higher and have a slope of 2-3% more than parcels of non-adopters. The topsoil of parcels with conservation measures tended to be deeper. Since the survey was conducted after adoption occurred, this might be a result, rather than a cause, of adoption. Seven major categories of soil type were identified for the region. The majority belonged to the category loam-clay. Although some of the soil types showed higher or lower rates of adoption, this is likely a spurious correlation, and relates to the fact that in certain communities where a given soil is prevalent, there is a greater tendency to adopt.

6.2 Farmers' perspectives on adoption

When improvements were adopted on a parcel (528 parcels), the farmer was asked a number of questions about conservation and the effects of conservation. The answers to these questions are presented in Table 7. The majority of farmers were still in the process of implementing the adopted conservation measures and only 14% reported having completed the work. Nearly all (93.8%) claimed to be maintaining the improvements they made in the past. With conservation, 72.6% of farmers introduced new crops.[13] Of those that did not introduce new crops, 47.6% introduced a new rotation. In total, 85.7% of farmers in some way altered their agricultural practices when they adopted conservation measures. This suggests that farmers viewed the new agricultural practices as complementary to conservation. Not surprisingly, this number was significantly higher for participants in the PROMUSTA program (86.9% versus 60%). Only 6.9% of farmers obtained credit in order to invest in conservation. Some form of incentive was given to 51.9% of farmers, including seeds, plants and other inputs. Even non-participating farmers received incentives of some form, most likely from other conservation projects. Seeds and plants were the most common incentives received. Cash incentives or direct labor payment (cash or food) were not given.

[13] New crops include fruit trees, vegetables and cultivated pastures.

Table 7. Adoption of parcel improvements.

		Total	Non-part.	Participant	Test
Number of parcels		528	25	503	-
	% of total	100.0%	4.7%	95.3%	-
Questions asked of farmers that adopted parcel improvements					
Status					
Year conservation was started		1992.3	1990.6	1992.4	-2.67 ***
Work is completed		14.0%	28.0%	13.3%	4.28 **
Work is being maintained		93.8%	96.0%	93.7%	0.21
New crops introduced with conservation		72.6%	56.0%	73.4%	3.62 *
	If no, new rotation introduced	47.6%	9.1%	50.7%	7.07 ***
Farmer changed agricultural practices		85.7%	60.0%	86.9%	14.00 ***
Credit and incentives					
Credit obtained for conservation		6.9%	4.0%	7.1%	0.35
Incentives received for conservation		51.9%	32.0%	52.8%	4.15 ***
	Seeds received	31.5%	8.0%	32.7%	6.73 ***
	Plants received	25.4%	20.0%	25.6%	0.40
	Other inputs received	8.8%	8.0%	8.8%	0.02
Soil quality					
Before†	Good	14.7%	24.0%	14.3%	3.93
	Regular	48.1%	56.0%	47.8%	
	Poor	37.1%	20.0%	38.0%	
Now†	Good	68.2%	64.0%	68.5%	1.03
	Regular	29.4%	36.0%	29.2%	
	Poor	2.2%	0.0%	2.4%	
Difference†	Better	70.0%	52.0%	70.8%	5.50 *
	Same	28.0%	48.0%	27.0%	
	Worse	2.1%	0.0%	2.2%	
Soil moisture					
Before†	Good	17.2%	12.0%	17.4%	7.79 **
	Regular	40.4%	68.0%	40.0%	
	Poor	41.4%	20.0%	42.4%	
Now†	Good	65.5%	64.0%	65.6%	0.65
	Regular	32.7%	32.0%	32.7%	
	Poor	1.9%	4.0%	1.8%	
Difference†	Better	67.5%	56.0%	68.1%	3.08
	Same	29.7%	44.0%	28.3%	
	Worse	2.8%	0.0%	2.9%	
Soil erosion					
Before†	Very serious	51.5%	32.0%	52.5%	5.37 *
	Serious	33.8%	40.0%	33.5%	
	Not very serious	14.7%	28.0%	14.1%	
Now†	Very serious	3.9%	0.0%	4.1%	1.15
	Serious	25.4%	24.0%	25.4%	
	Not very serious	70.7%	76.0%	70.4%	
Difference†	More serious	2.6%	0.0%	2.7%	7.58 **
	Same	22.2%	44.0%	21.1%	
	Less serious	75.2%	56.0%	76.1%	

Table 7. Adoption of parcel improvements (continued).

Overall impact				
Effect of conservation measures and changes in practices on the value of production†				
Increased	82.7%	72.0%	83.2%	6.50 *
No change	8.7%	20.0%	8.2%	
Lower	1.1%	4.0%	1.0%	
Don't know	7.5%	4.0%	7.6%	
Perspective on adopted changes†				
Worth it	93.4%	84.0%	93.9%	9.22 ***
Not worth it	2.2%	0.0%	2.4%	
Don't know	4.3%	16.0%	3.7%	
Extentionist agents observations				
Appropriateness of parcel improvements†				
Very appropriate	58.4%	36.0%	59.5%	7.41 **
Somewhat appropriate	38.6%	64.0%	37.4%	
Not appropriate	3.0%	0.0%	3.1%	
Percent of the parcel adequately managed	59.9%	44.2%	60.6%	-2.59 ***

†test is for joint significance

Farmers were asked to evaluate soil quality, soil moisture and soil erosion on their parcels before conservation and at the time of the survey. The results show a strong majority of farmers, including both participants and non-participants, believed conservation improved soil quality and moisture and reduced soil erosion on the plot in question. Seventy percent of farmers said soil quality was better, 67.5% said soil moisture was better and 70.7% thought soil erosion was less of a problem. In general, participants gave favorable evaluations of conservation. This could be because the practices they used were more appropriate or better managed, or because they understand the process better and were thus able to evaluate the benefits of conservation differently. In an extremely positive response for the project and one with implications for the sustainability of the improvements, on parcels with conservation measures, 82.7% of farmers noted that conservation and changes in cultivation increased the value of production and 93.4% of farmers thought the adopted changes were worth the effort.

Extension agents were asked to evaluate the parcel level improvements. Fifty-eight percent of the time, parcel improvements were considered very appropriate and 39% of the time extensionist agents rated improvements as somewhat appropriate. Correspondingly, extension agents noted that, for those parcels with improvements, on average 60% of the improved parcel was adequately managed.

6.3 PROMUSTA technologies

The PROMUSTA program offered a wide range of technologies from which the farmers, in consultation with extension agents, could choose. Appendix 1 provides a detailed description of most of the technologies adopted by farmers. The technologies adopted can be grouped into 10 types of improvements, and more broadly into two groups: resource conservation; and, agricultural intensification and diversification. The groupings and improvements are categorized as follows:

Resource conservation

1. *Control of water erosion* (water runoff channels, hilling along the contour, bunds)
2. *Improved water management* (reservoirs, irrigation canals)
3. *Slow-forming terraces*
4. *Bench terraces*

Agricultural intensification and diversification

1. *Biological barriers* (trees and/or grasses on borders)
2. *Agroforestry* (nurseries for trees, planting of trees on slopes)
3. *Soil quality improvements* (worm culture, composting, organic fertilizers)
4. *Agricultural diversification* (vegetable plots, fruit trees, horticulture, greenhouses, cultivated pastures)
5. *Improved agriculture* (new rotation, improved crops, better management)
6. *Improved animal management* (management of small animals, trout farming)

Since these technologies were only explicitly offered to PROMUSTA participants, we only considered their parcels. Of the parcels owned by PROMUSTA participants, 503 of the 616 (81.7%) had some form of improvement. Each household was asked to list the technologies they adopted for the parcel (Table 8). Most parcels had multiple improvements (see first row, total parcels): 69.2% adopted at least one resource conservation measure and 66.1% altered agricultural production. The most common actions taken were water erosion control measures (42.2%), bench-terraces (33.4%) and agroforestry (36.5%). Since terraces also control water erosion, explicit erosion reduction practices are a major contribution of PROMUSTA. Biological barriers, which were adopted on 23.5% of parcels, often included the planting of trees. If both biological barriers and agroforestry are considered, the planting of trees is another major impact of the PROMUSTA program.

The diversity of actions reported is interesting since it shows the richness of the program. Table 8 shows the interaction between technologies. For each improvement adopted, we examined the other improvements also adopted. We also did this in general for resource conservation and agricultural changes. For example, 77.6% of parcels that included a resource conservation technology also had some change in agricultural practices. Using a chi-squared test, we can determine if this is significantly different from parcels in general (where 66.1% adopt new agricultural practices). With 99% confidence, we can say that parcels with a resource conservation technology are more likely to have changed agricultural practices. Similarly, 82.1% of parcels with agricultural changes also have resource conservation measures.

One result of comparing adopted technologies is that few clear patterns emerge. Farmers typically did not adopt technologies as packages but rather selected components appropriate for their parcel and household conditions. PROMUSTA extension agents are trained to present the range of technologies as a menu of possible choices. Only in limited instances are there recommendations of coupled technologies. The lack of patterns suggests that the menus of technologies adopted are exceptionally household- and parcel-specific. However, looking at the individual technologies, a few generalities can be noted. More than 17% of parcels with a technology to control water erosion also had an improved water management technology and 59.0% of parcels with improved water management also controlled water erosion. These are significantly higher than the overall percentages (12.7% and 42.2%). Parcels with bench terraces also tended to have water erosion control technologies. A parcel with a slow-forming terraces was significantly less likely to have bench terraces on the same parcel (4.9% compared to 13.8%). Correspondingly, parcels with bench terraces were significantly less likely to also have slow-forming terraces (11.8% compared with 33.4%). This is not surprising since the two types of terraces are generally regarded as substitutes. In an example where coupled recommendations did have an impact, biological barriers were more likely to occur with resource conservation measures including control of water erosion and bench terraces. PROMUSTA extension agents recommended terrace and waterway stabilization with living barriers and trees, and biological barriers are complementary to resource conservation. Farmers that took actions on their parcels to improve soil quality were more likely to do so in conjunction with agricultural diversification and improved agricultural practices. Better soil quality was considered by many farmers to be complementary to crop diversification and changing agricultural patterns.

Table 8. Parcel-level adoption of PROMUSTA technologies.

Number of parcels = 616

	Resource conservation						*Agricultural intensification and diversification*					
	Resource conservation	Control of water erosion	Improved water management	Slow-forming terrace	Bench terrace	*Agric. intens. & divers.*	Biological barriers	Agroforestry	Soil quality improvement	Agricultural divers.	Improved agricultural practices	Improved animal management
Total parcels	69.0%	42.2%	12.7%	13.8%	33.4%	66.1%	23.5%	36.5%	19.3%	20.1%	11.0%	5.2%
Resource conservation	-					77.6%***						
Control of water erosion		-	17.7%***	10.8%*	38.5%**		30.4%***	42.3%**	19.6%	17.3%	10.7%	4.2%
Improved water management		59.0%***	-	12.8%	39.7%		25.6%	41.0%	16.7%	20.5%	6.4%	2.6%
Slow-forming terrace		32.9%*	11.8%	-	11.8%***		28.2%	48.2%**	25.3%*	21.2%	12.9%	7.1%
Bench terrace		48.5%**	15.1%	4.9%***	-		30.1%***	42.2%**	18.9%	22.1%	8.7%	5.3%
Agric. intensification & diversification	82.1%***					-						
Biological barriers		54.5%***	13.8%	16.5%	42.8%**		-	41.4%	22.8%	22.8%	11.7%	6.2%
Agroforestry		48.9%**	14.2%	18.2%**	38.7%**		26.7%	-	21.8%	26.2%***	8.4%	7.6%**
Soil quality improvement		42.9%	10.9%	18.5%*	32.8%		27.7%	41.2%	-	34.5%***	21.9%***	12.6%***
Agricultural diversification		36.3%	12.9%	14.5%	37.9%		25.8%	47.6%***	33.1%***	-	10.5%	10.5%***
Improved agricultural practices		41.2%	74.0%	16.2%	26.5%		25.0%	27.1%	38.2%***	19.1%	-	11.8%***
Improved animal management		34.4%	6.3%	18.8%	34.4%		28.1%	53.1%**	47.9%***	40.6%***	25.0%***	-

*= significant at 90%, **= significant at 95%, ***=significant at 99% level .

Certain technologies may be more likely to be adopted on a subset of parcels with particular characteristics. In Table 9, we compare adoption of each technology across different parcel characteristics.

Slope. Resource degradation is expected to be greatest on steeper-sloped parcels and therefore conservation measures more likely. In general, adoption of resource conservation measures increased with slope, particularly as the slope increases from near flat parcels to medium-sloped parcels. This difference was most striking for bench terraces. Only 22.2% of farmers put bench terraces on parcels with 0-12% slope while over double that percent (46.3%) put bench terraces on parcels with a slope of 25-36%. Note that this number dropped to 35.4% for very steep slopes (>36%). This could be because of the difficulty of terracing such steep slopes. Slope does not appear, in general, to be strongly related to changes in agricultural practices. The very steep parcels were more likely to have agroforestry measures enacted and biological barriers. The flattest parcels were more likely to have soil quality improvements and agricultural diversification.

***Altitude*.** The parcels showed a variable response to conservation adoption in relation to altitude. In general, as altitude increases towards and above 3,000 meters, adoption of all conservation was more likely. In all cases, the highest level of adoption was for altitudes between 3100 and 3500 meters, and adoption tended to drop off for altitudes above 3500. In general, measures to intensify and diversify agriculture tended to be uniform across altitudes. Agroforestry was highest for mid-range altitudes. Soil quality improvements and agricultural diversification were highest for lower altitudes. The explanation for the drop-off above 3,500 comes from two potential sources: the upper limit of agriculture and the legality of farming the paramo. Temperature, frost risk and rainfall are important determining factors in the distribution of crops, and, in general, rainfall and frost risk increase with altitude. The paramo, starting at altitudes between 3,400m. and 3,500m., marks the effective upper limit of agriculture. Because of low temperatures and high frost risk, agriculture is a marginal proposition in the paramo. Further, the paramo was traditionally viewed as communal land and during the land reform was preserved as such. But there has been a progressive invasion of the paramo for agricultural purposes from communities that border it. Laws have been passed to discourage this invasion. Agriculture in the paramo is typically seen as purely exploitative; farmers clear the grassland, take advantage of the natural fertility to lower costs of crop establishment and possible loss for a

Table 9. Adoption and parcel characteristics.

		Resource conservation					*Agricultural intensification and diversification*					
	Percent of total	*Resource conservation*	Control of water erosion	Improved water management	Slow-forming terrace	Bench terrace	*Agric. intens. & divers.*	Biological barriers	Agroforestry	Soil quality improvement	Agricultural diversification	Improved agricultural practices
Slope (%)												
0-12%	32.8%	59.9%	35.2%	10.9%	12.4%	22.2%	66.8%	24.3%	32.7%	24.8%	24.3%	10.9%
13-24%	21.8%	73.1%	45.5%	14.9%	14.9%	35.1%	65.7%	20.1%	38.8%	14.2%	17.2%	11.9%
25-36%	22.1%	74.3%	49.3%	13.2%	11.8%	46.3%	63.2%	17.7%	30.9%	16.2%	21.3%	12.5%
> 36%	23.4%	72.9%	42.4%	12.5%	16.7%	35.4%	68.1%	30.6%	45.1%	19.4%	16.0%	9.0%
Altitude (meters)												
< 2700	17.5%	48.2%	22.2%	9.3%	9.3%	23.2%	64.8%	24.1%	29.6%	25.9%	29.6%	7.4%
2700-3099	31.8%	71.9%	41.8%	13.8%	13.3%	29.6%	69.9%	22.5%	39.8%	22.5%	24.0%	14.3%
3100-3499	39.1%	74.7%	48.9%	15.4%	16.6%	40.7%	64.3%	23.7%	37.7%	14.9%	12.9%	9.1%
≥ 3500	11.5%	73.2%	50.7%	5.6%	12.7%	35.2%	63.4%	25.3%	33.8%	15.5%	19.7%	14.1%
Parcel area (hectares)												
< 0.1	21.9%	65.2%	33.1%	13.3%	14.1%	28.9%	58.5%	21.5%	23.7%	21.5%	20.0%	6.7%
0.1-0.24	27.7%	64.3%	40.4%	8.2%	8.8%	35.1%	62.0%	26.9%	30.4%	17.5%	21.1%	15.2%
0.25-0.49	21.8%	73.5%	47.3%	16.0%	12.2%	39.7%	74.8%	25.2%	48.1%	26.7%	17.9%	11.5%
0.5-0.99	16.7%	70.1%	52.0%	20.6%	17.7%	30.4%	63.7%	22.5%	35.3%	17.7%	18.6%	9.8%
≥ 1.0	12.5%	70.1%	44.2%	5.2%	22.1%	31.2%	76.6%	18.2%	54.6%	19.5%	20.8%	10.4%
Rainfall (mm/year)												
< 500	32.1%	79.3%	53.0%	24.2%	12.1%	42.9%	64.6%	22.7%	36.9%	20.2%	22.2%	9.1%
501-700	32.6%	66.7%	42.8%	9.0%	12.4%	31.8%	65.7%	25.4%	33.3%	20.4%	19.9%	16.4%
> 700	35.2%	61.8%	31.8%	5.5%	16.6%	26.3%	67.7%	22.6%	39.2%	17.5%	18.4%	7.8%

few years, and then abandon the field. Thus high altitude lands are both agriculturally and legally marginal, reducing the incentive to invest in conservation.

***Parcel size*.** If a technology exhibits economies of scale it may be more likely to be utilized on larger parcels. If it requires intensive use of labor it may be more utilized on smaller plots. Examining parcel size, we see that conservation measures were more likely to occur on plots of 0.25 hectares or more. Control of water erosion generally increased with parcel size and was most likely to occur on parcels between 0.5 and 1.0 hectares. Slow-forming terraces were most likely on larger parcels probably because they require less labor and bench terraces were most likely on medium-size plots because they are more labor intensive. As with resource conservation, changes in agricultural practices tended to be adopted on parcels larger than 0.25 hectares. This result is primarily the due to the higher adoption of agroforestry on larger parcels.

***Rainfall*.** Data were available for rainfall only at the community level. Though using these data runs the risk of attributing a community effect to rainfall patterns, there were clear trends in the patterns of adoption that might be explained by rainfall differences. In contrast with intensification and diversification, adoption of resource conservation measures was much more likely in areas with less rainfall. With the notable exception of slow-forming terraces, adoption of each technology decreased with rainfall. Terraces deepen soil and improve its water holding capacity. Thus the benefits of terracing are more clearly perceived in dryer areas. This suggests that conservation may be a method for using water resources more effectively rather than for conserving the soil. Trends in agricultural intensification and diversification tended to be ambiguous with no clear patterns emerging.

6.4 Resource conservation and agricultural changes

At the beginning of this section, we noted that soil conservation programs in developing countries have a mixed history of success. Programs using incentives to induce conservation often resulted in abandonment when incentives were withdrawn. The CARE-PROMUSTA model offers a technological menu that includes conservation measures and changes to agricultural production rather than offering incentives to improve short-run returns to conservation. The changes in production allow short-run returns to adoption and are often complementary to conservation thus inducing long-term conservation. Two sets of results at the parcel level point to the success of this model. First, from the farmers' perspective, a majority of participants adopted not only conservation measures, but altered their agricultural practices. More than two-thirds of adopting farmers noted that adoption improved soil quality and soil moisture and reduced erosion. More than 80% of adopters noted that the innovations improved the value of production. Farmers then perceived the short-term gains in profitability and the long-term gains in reduced erosion. In addition to farmers' perceptions, farmers' actions also pointed to the success of the model. In general, more than 80% adopted some practices, with the majority adopting both resource conservation and changing agricultural production. Farmers will not adopt unless it is beneficial to do so. The extreme variability of technologies adopted suggests farmers chose items that were most applicable to their own situation.

The results thus far suggest the complementarity of resource conservation and changes to agricultural production, but they fall short of a direct test of this hypothesis. Such a test is difficult because of the complexity of the PROMUSTA program. For this reason, we have chosen to focus only on the adoption of terraces. Although not the only method of resource conservation, terraces — both bench and slow-forming terraces — represent an important one. The question we want to answer is whether terraces are more likely to be adopted if complementary changes in the agricultural production system occur; specifically, agricultural diversification and the adoption of biological barriers. Since the decision to terrace is discrete, a probit can be used to determine the factors that influence terracing. The presence of agricultural diversification or biological barriers is assumed to enter the decision on terracing exogenously. This is a questionable assumption given that these decisions can be viewed as simultaneous and thus related. A test for endogeneity was done and we present the results of such a test in Appendix 2. The test shows that treating the variables as exogenous is acceptable. The results of the probit on the decision to terrace are presented in Table 10. Of the 616 parcels owned by PROMUSTA participants, 45.7% adopted terraces, 20.2% diversified agriculture, and 23.5% planted biological barriers.

Table 10. Probit on terrace adoption.

	Marginal effect	*t-test*
Land characteristics		
Parcel size	0.002	0.20
Slope	0.004	3.06 ***
Altitude	-0.00003	-0.33
Human capital assets		
Male labor/ha.	0.005	1.94 *
Female labor/ha.	-0.005	-1.90 *
Age of head	-0.001	-0.49
Education level	0.020	1.65 *
Off-farm income	0.0009	1.14
Physical assets		
Value of animals owned	-0.00002	-0.11
Community characteristics		
Years community with CARE	0.054	5.44 ***
Distance to city (pop>50,000)	-0.002	-1.82 *
Population density	0.083	2.74 ***
Rainfall	0.001	5.37 ***
Complementary actions		
Agricultural diversification	0.159	2.82 ***
Biological barriers	0.163	3.12 ***
Regions		
Azuay	-0.007	-0.07
Cañar	-0.485	-6.13 ***
Chimborazo	-0.147	-1.90 *
Cotopaxi	0.225	2.25 **
Imbabura	-0.360	-3.73 ***
Loja	-0.454	-5.05 ***
Constant	-	-2.53 **

*= significant at 90%, **= significant at 95%, ***=significant at 99% level .

The marginal effect is calculated at the sample mean.
Four observations were dropped due to missing data.

	Predicted terrace	**Predicted no terrace**
Terrace	182	96
No terrace	86	248
Percent correct	67.9%	72.1%
Total percent correct	70.3%	

Not surprisingly, farmers with more sloped parcels were more likely to adopt terraces. For every 10% increase in slope the probability of adoption increased 4%. Households with more male labor per hectare were more likely to adopt terraces and households with more female labor per hectare were less likely to adopt. This is probably due to the high labor requirements of terracing and the physical effort required for terraces. Farmers noted in informal conversations that terracing was "work for men." Educated households were more likely to adopt terraces, possibly because they are more capable of processing the information on technologies presented by extension agents. Terracing was more likely to occur later in the PROMUSTA program. This is shown by the positive coefficient on the variable "years community with CARE." Adoption of terraces may be slowed by the fact they require significant labor inputs. Additionally, prior to adoption, farmers may want to gather information on the benefits of terracing from neighbors' experiences or their own experimentation, and may delay adoption on all or some parcels. On average, each year the probability of terrace adoption increased 5%. The distance to a city was found to negatively impact the decision to terrace, which suggests farmers closer to cities were more likely to put in terraces. In general, land markets are thought to function better near cities where land values are often higher. The higher adoption rate may reflect a higher value for land and a return to investing in land. Population pressure was found to positively influence the decision to terrace. Farmers may be pushed to take action only when land is scarce. Rainfall was found to positively and significantly impact the probability of terracing. For every 100 mm increase in rainfall, the probability of terracing increased 10%. Both agricultural diversification and biological barriers were found to be complementary to terracing and to strongly induce the adoption of terraces. The presence of agricultural diversification increased the probability of adoption by 15.9% and the presence of biological barriers increased the probability of adoption by 16.3%. Without a complementary package of technologies, the adoption of terraces would have been less. Finally, a number of regions were found to have different adoption rates than the province of Tunguragua. Provinces roughly correspond to the administrative units of the PROMUSTA program. Differences could be due to differences in emphasis across provinces or differences in physical or socio-economic factors.

7. Household decision making and the intensity of adoption

Examining household adoption requires an understanding of household objectives, which vary according to household characteristics such as education, age and wealth, and may be limited by market, technology and resource constraints. Variability in adoption across households therefore results from differences among household characteristics, and constraints. In their survey of the literature on technology adoption, Feder, Just, and Zilberman (1985) cite several factors that influence the adoption decision, such as[14]:

1) The probability of adoption increases with the stock of information presented, for example, by extension agents (Hiebert, 1974).
2) The better the physical environment (in terms of soil quality, water access, etc.), the greater the likelihood of adoption.
3) The adoption of a technology depends on whether it is risk increasing or risk reducing and whether risk aversion increases or decreases with income (Just and Zilberman, 1983).
4) A positive relationship between farm size and adoption may be due to fixed transaction costs associated with the acquisition of new information. This may lead to a lower limit on the size of adopting farms (Just, Zilberman and Rauser, 1980; Feder and O'Mara, 1981).
5) Adoption of a labor-demanding technology may be discouraged by labor-market shortages. Additionally, under certain assumptions (such as elastic output demand), the likelihood of adoption of a "lumpy" labor-saving technology is higher if there is uncertainty in the labor market (Zilberman and Just, 1984).
6) Given a package of technologies, one component (which does not incur fixed adoption costs) may be adopted by all farmers while lumpy innovations may only be adopted by farmers larger than a certain size (Feder, 1982).
7) The length of time between awareness of a technology and the adoption of that technology is negatively associated with mean profit and positively associated with profit variance (Lindner et al, 1979).
8) Assuming smaller farmers are more risk-averse, the lag time for adoption may be shorter for small farmers if a higher risk innovation is not well correlated with the old technology. The reason is that the innovation offers diversification of risk (Just and Zilberman, 1983).
9) Farmers with better education tend to be early adopters and use new technologies better than those with less education, presumably because they have a higher opportunity cost of their resources and are more efficient in acquiring technical knowledge.
10) Supply constraints to complementary inputs inhibit adoption since they reduce the return to adoption.

[14] Citations are from Feder, Just, and Zilberman (1985).

Feder, Just and Zilberman also present a number of themes that are of interest to our present study. First, they note that much of the literature on adoption considers the discrete decision of whether or not to adopt an innovation. This ignores the intensity of adoption; defined as the percentage of farm land on which the innovation is being used. Technological innovations can be defined as divisible and indivisible. For an indivisible innovation, such as a tubewell, examining the discrete adoption decision is a reasonable approach. Divisible innovations, however, may be used on only a part of the farm. Examining adoption for a divisible innovation as a discrete decision lumps farmers with 1% to 100% adoption together and provides no information on the distinction between higher and lower levels of adoption. In our present study, households may, and usually do, adopt on only a portion of their total land. We then examine the intensity of adoption and focus on why the pattern of adoption differs across households.

A lack of information on a new technology or set of technologies is one possible explanation for gradual adoption. Information flow is often cited as the reason for the S-shaped pattern of aggregate adoption. This pattern suggests adoption begins with a few early adopters, who are followed by the majority of the population — “followers” — and finally by late-comers to the technology, or “laggards” (Rogers, 1962). The flow of information on the use and profitability of the new technology explains the diffusion pattern. Communication of an innovation by agricultural extension agents or other sources leads to initial adoption of the technology. Once the diffusion process has begun, and some innovators have accepted the technology, other households may decide to adopt a technology based on information gained by observing the actions of their neighbors; a process referred to as “learning from others” (Foster and Rosenzweig, 1995). The diffusion process accelerates with the expansion of general knowledge regarding the technology. Variations in the shape of the S-curve are likely even for the same technology due to differences in profitability between regions.

The partial adoption of a divisible innovation by a household may be motivated by similar informational constraints. Besley and Case (1994) argue that the uncertain profitability of an innovation leads to partial adoption. Using information gathered from their own experience with a technology or from their neighbors experience, farmers update their expectations about the actual profitability of the technology. Along similar lines, Foster and Rosenzweig (1995) argue information on the best use of inputs for a new technology is unknown and stochastic. Experimentation or learning from neighbors' actions leads to a better understanding of best input use. In either case, limited information is likely to lead farmers to initially allocate only some of their land to the new technology. As information about the technology increases, the household adjusts its land allocation accordingly.

If information constrains adoption then the ability to obtain and use information should then influence the intensity of adoption. Farmers with a higher level of education, and presumably a better ability to grasp new concepts, are likely to have a higher intensity of adoption. If obtaining initial information on adoption is costly, then larger farmers may be more likely to adopt since they can more easily recoup the costs of adoption. The more comprehensive the information presented by extension agents the higher the level of adoption. Participation in the PROMUSTA program, where information on resource management is presented, should therefore strongly influence adoption.

Another variable affecting the intensity of adoption of a new technology is labor availability. The technology itself may require more (labor demanding) or less (labor saving) labor than a previous production technology. Adoption is then influenced by how the labor market functions. If there tend to be labor shortages at peak demand times, and it is at these times that the new technology requires labor inputs, then this may inhibit adoption. For resource conservation measures, particularly physical structures which tend to require a great deal of initial labor investment, investment may be inhibited by labor availability. While the new production technology may not be labor intensive, the investment may be labor intensive. The intensity of adoption may be related to the availability and value of labor. If labor is abundant and low cost then farmers can invest more quickly than if labor is in short supply and costly. When questioned, farmers regularly note that labor availability inhibits the speed of adoption within the farm. Since conservation measures and changes in production must occur before the growing season, it is labor availability at this time that matters. During this off-season, farmers allocated labor such that the discounted stream of future net benefits to conservation is equal to the opportunity cost of labor in the present period. The higher the opportunity cost of labor, the lower the investment in conservation. Investment and the intensity of adoption should then be related to the opportunity cost of labor. Farmers with the ability to obtain off-farm labor income from day labor or temporary migration are less likely to adopt.

Since conservation tends to require heavy labor it is generally the domain of males. The number of males in the household per unit of land can therefore influence the ability to adopt.

7.1 Intensity of adoption

To examine the intensity of adoption, data on the percent of land area "properly managed" was determined for each household. This was done by evaluating the resource management practices of every parcel operated by each farmer and determining the area of land that was managed in an appropriate manner (based on CARE's criteria). Summing over all the land operated by the household, an intensity of adoption was calculated. The data is censored at 0% and 100% where 0% means that no adoption occurred and 100% meaning full adoption. Of the 525 households included in the analysis[15], 26% did not adopt any new practices and thus had an intensity of adoption of 0%. Ten percent adopted the appropriate technologies on all their land and the remaining 64% were somewhere in between. Of those with an intermediate level of adoption, the average percent of adoption was 46%.

In order to examine the importance of labor and informational constraints, we regressed the intensity of adoption on a number of relevant variables including those discussed above. Since the dependent variable (intensity of adoption) is censored on both sides of the distribution, a double-censored regression model is appropriate. In the regression, we wanted to examine the importance of PROMUSTA membership on the intensity of adoption. One means of doing this is to include a dummy variable[16] that presumably measures the influence of membership on adoption. The problem with this specification is that it may be the case that PROMUSTA members would have adopted the new technology even if PROMUSTA had not intervened. The coefficient on the dummy variable is then not measuring the effects of PROMUSTA, but that those that decide to join PROMUSTA are likely adopters. Econometric techniques have been developed to avoid this self-selection bias.[17] This involves using the residuals of the probit on PROMUSTA participation (Table 4) to create a selectivity correction for the regression. This was what was done here.

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[15] Five observations were dropped for this analysis due to missing data.
[16] A variable that takes the value of one for participants and zero for non-participants.
[17] See Greene (1997) chapter 20, section 20.4 for a discussion of selection problems.

Ideally, data on the intensity of adoption would be collected at more than one period of time. The data we have is cross-sectional and we therefore must control for the time since introduction of a new technology. As noted earlier, time is important in the adoption of technology. Information on a technology is presumably better over time since information is improved as farmers experiment with the technology. If labor is a constraining factor in adoption and is only allocated to adoption between seasons, then each year's labor allocation increases adoption. In both cases it this expected that the intensity of adoption is positively related to the number of years the technology has been available. Other farm, household and community characteristics may also influence adoption and are included in the regression.

Table 11 provides the results of the regression on intensity of adoption. The amount of male labor per hectare positively and significantly affected the intensity of adoption. Female labor negatively impacted the intensity of adoption. This suggests that households require male labor to invest in resource conservation and households endowed with large amounts of female labor are less likely to invest, or will invest more slowly, in conservation. The age of the head of the household was negatively related to the intensity of adoption. Presumably the head of the household, normally the eldest male, was the primary decision maker. The results suggest that younger household heads were more likely to push for adoption or were more likely to adopt more quickly. Education was positively and significantly related to adoption intensity. As suggested above, households with more educated members were likely to be more receptive to new information. The amount of off-farm income was not found to be significant. Taken together, these results indicate that both labor constraints for male labor and information availability are important in determining the intensity of adoption.

Physical assets, as measured by total land owned and value of animals owned, were not found to significantly affect adoption. Neither the slope of the steepest plot a farmer operated nor the altitude of the highest plot a farmer operated was found to significantly influence adoption. The distance to a large town measures access to markets and correspondingly, land values. The closer the household was to town, the higher the intensity of adoption. This may be because access to markets allows a higher return to changes in agricultural production. Correspondingly, it could be that land markets function better near cities and therefore farmers are more able to capture returns to investments in

Table 11. Intensity of adoption.

	Coef.	*Marginal effect*	*t-test*
Human capital assets			
Male labor/ha.	0.33	0.17	1.91 *
Female labor/ha.	-0.28	-0.15	-1.77 *
Age of head	-0.25	-0.13	-1.76 *
Education level	2.08	1.10	2.06 **
Off-farm income	-0.01	-0.005	-0.14
Physical assets			
Land owned	-0.59	-0.31	-0.92
Value of animals owned	0.0001	0.00007	0.10
Land characteristics			
Slope of steepest parcel	0.02	0.01	0.18
Altitude of highest parcel	0.01	0.005	1.05
CARE-PROMUSTA			
Participation in project†	99.86	32.10	7.73 ***
Community characteristics			
Years community with CARE	3.17	1.68	4.12 ***
Distance to city (pop>50,000)	-0.16	-0.09	-1.98 **
Population density	2.52	1.33	1.09
Rainfall	0.014	0.008	0.93
Regions			
Azuay	-11.42	-6.04	-1.40
Cañar	-25.04	-13.25	-2.99 ***
Chimborazo	10.51	5.56	1.57
Cotopaxi	-10.51	-5.56	-1.31
Imbabura	-1.45	-0.77	-0.16
Loja	-17.98	-9.51	-1.84 *
Inverse Mill's ratio	-12.97	-	-1.69 *
Constant	-81.27	-	-2.58 ***

*= significant at 90%, **= significant at 95%, ***=significant at 99% level .
The marginal effect is the impact of the variable on adoption given censoring.

conservation. Population density and rainfall were not found to influence adoption. Regional dummies show that there were significant differences in adoption across some regions. In particular, Cañar and Loja were found to have significantly lower intensities of adoption. The reason for this should be explored.

The single most important determinant of adoption was participation in the PROMUSTA program. Given censoring, adoption intensity of participants was 32.1% higher than the adoption intensity of non-participants. Much of this is due to the fact that non-participants did not adopt at all. This suggests that adoption of these technologies would have been substantially lower if the PROMUSTA program had not been active. The number of years in which CARE worked with the community positively affected the intensity of adoption. This means that over time households were managing more land in a manner consistent with the PROMUSTA program.

8. Impact assessment

PROMUSTA objectives were to stimulate sustainable agriculture through resource conservation and agricultural diversification and intensification. Using the data gathered in the survey, we were able to partially assess how well PROMUSTA has met these objectives. Though the selection of communities included in this survey was, strictly speaking, not random, the community selection criteria were designed to identify representations of the variability in the set of communities collaborating in PROMUSTA. Individuals within communities were selected randomly. Supposing the survey captures an unbiased sample of PROMUSTA participants, a simple extrapolation of the results indicates some benefits of PROMUSTA.

Although the beneficiaries of PROMUSTA include non-participating farmers and off-farm beneficiaries of improved resource management, direct benefits mostly accrue to participating farmers. PROMUSTA has worked with nearly 10,000 families in 193 communities. The benefits to these farmers are an increased value of current production and a higher value of future production due to the sustainable management of resources. Determining a numerical value for the benefits is difficult and not possible with the available data. Instead we examined the actions households have taken and farmers' perceptions of the value of production (Table 12). Of the 9,333 households participating in the PROMUSTA program 413 were surveyed. Nine of 10 of these households adopted some part of the PROMUSTA technological package, suggesting that a total of 8,384 Ecuadorian farmers in some way altered their agricultural system. Assuming adoption only occurred when there was an anticipated benefit, then this suggests more than 8,000 households benefited from the PROMUSTA program. Three-quarters of surveyed households reported improved income as a result of program participation implying more than 7,000 households realized short-term improvements in income. Sixty percent of farmers noted soil improvements indicating they perceived long-term benefits of adoption. Eighty-five percent of participating households — 95% of those that adopted some practices — noted that the activities undertaken were worth the effort. Therefore, nearly 8,000 of the 9,333 households participating in the PROMUSTA program found the program valuable.

Table 12. Impact of PROMUSTA.

Economic value	***Sampled participant households***	***Percent sampled households***	***Total participant households***
Number of households	413	100.0%	9333
Adoption of some practices	371	89.8%	8384
Improved income	312	75.5%	7051
Soil quality improvement	248	60.0%	5604
Activities worth the effort	353	85.5%	7977
Resource management (land)	***Sampled land area****	***Percent sampled land area***	***Total land area****
Area (hectares)	480	100.0%	10847
Appropriately managed	174	36.3%	3932
With terraces	183	38.1%	4135
With control of water erosion	187	39.0%	4226
With improved water management	36	7.5%	814

* Participant operated land

The 413 participant households that were surveyed operated 480 hectares of land. Assuming a similar level of land operation, participating households in total operated 10,852 hectares of land. Using CARE's criteria, 42.1% of land operated by participants was managed better (at the time of the 1996 survey). This suggests that 4,572 hectares of land were being managed in a sustainable manner.[18] Additionally, 4,808 hectares had terraces, 5,019 hectares had measures that help control water erosion and 946 hectares had improved water management (reservoirs and irrigation systems).

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[18] We are implicitly assuming that prior to interaction with CARE, farmers did not manage their land in a sustainable way.

The benefits discussed here should be considered conservative estimates for two reasons. First, only benefits to participating households are discussed. Presumably, non-participating households will adopt a number of the practices promoted by PROMUSTA and will receive benefits as well. Additionally, improved resource management should reduce erosion and limit the off-farm negative externalities. Second, as noted in both the probit on terracing (Table 10) and the intensity of adoption regression (Table 11), adoption of conservation technologies takes time. As the households continue to adopt these practices, more land will become managed in a more sustainable manner. These benefits are yet to be felt but the results indicate they are likely to come.

9. Conclusions and suggestions for further research

The data collected from the farmers in the 44 PROMUSTA communities indicate that the PROMUSTA program has been successful in improving resource management. Farmers noted improvements in both the land, as measured by soil quality, soil moisture and soil erosion, and in the value of production. Farmers have adopted a number of new practices on their parcels, including conservation practices and new agricultural practices. Overall, the intensity of adoption has been high in these communities, especially among participants. Each of these facts points to the overall success of the program.

There are a number of reasons for the success of the program. First, the menu of technological innovations offered to each household was extremely diverse. This allowed farmers to choose a set of options that fit their particular needs. Second, the menu included both conservation measures and complementary changes to agriculture. By altering the entire agricultural system, resource conservation has become embedded in the production technology. Although incentives were given for adoption, these usually came in the form of seeds, plants or inputs in production and were not direct payments for conservation measures.

The implication of this approach is that resource management improvements is more likely to be sustainable when used with an integrated resource management approach. That is, by integrating conservation in the agricultural system it is more likely to be adopted and maintained. Such a program requires a viable alternative agricultural system. Results indicate this may be easier to do near a market source such as a city. Identifying alternative sustainable agricultural systems and targeting these systems to appropriate areas is extremely important. This requires a well-organized extension system and knowledgeable extension agents. Information on agricultural potential for an area, as well as household characteristics and constraints, is important. As we have shown, the availability of male labor, an educated household and a young household head can impact the technological choices for the household. Recognizing these conditions can facilitate appropriate adoption.

Although the results presented here point to the success of the PROMUSTA program, additional research on the program would help confirm this conclusion and determine the parts of the program that were most valuable. Adopting farmers noted the increase in value of production. This study did not examine the costs and benefits associated with adoption, neither for the individual farmer nor for society as a whole. Future research could estimate the net benefits of adoption, both private and public. In times of budget austerity and competition for funds, demonstration of the benefits of the investment in programs such as PROMUSTA could help direct scarce resources toward productive uses.

A study of the net benefits of adoption could also examine in more detail the short- and long-term benefits of adoption and the benefits of individual technologies. We have argued that the short-term benefits induce adoption of resource conservation if such actions are complementary. Understanding the relationship between conservation measures and changes in the agricultural production system, would allow the development of programs that use this relationship to improve resource conservation. Comparing the value of production with and without conservation measures, *ceteris paribus*, would highlight the short-term benefits of conservation and determine which agricultural production systems are most complementary to conservation. Additionally, the diversity of technologies adopted by PROMUSTA participants indicates the value of technologies for each farmer varies. By examining the benefits of individual technologies across farm households, it is possible to identify the factors that influence the benefits of a given technology. Physical, climatic and socio-economic factors may matter.

One line of research could examine the public benefits of adoption. Off-farm benefits of conservation adoption depend largely on the types of on-farm actions taken. Certain types of actions may provide greater off-farm benefits. Research could determine which technologies produce the greatest off-farm effects and under what conditions these technologies will be adopted.

Finally, this study has used cross-sectional data from a single point in time. From the actions of farmers, it seems the program is sustainable and farmers will maintain the practices they have adopted. However, as with other programs, it is possible that once PROMUSTA has completely withdrawn from the communities adoption may stall and farmers may even abandon certain practices. A follow up study that surveys some of the same farmers and sees their progress over time would be a useful exercise. The spontaneous adoption by non-participant farmers can also be examined in the same study. The combination of the two could determine sustainability of adoption and the diffusion of the technologies.

The research agenda suggested here could possibly be examined in a single study focusing on fewer communities and a smaller sample of farmers. More detailed data could be gathered to understand the changes in the farming system and the resource conservation measures adopted, detailed cost-benefit analyses, and, by focusing on only a few watersheds, off-farm effects could also be examined.

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Appendix 1. Description of PROMUSTA technologies.

As part of the survey, farmers were asked to identify the technologies adopted on each parcel. Farmers identified the following technologies.[17] Note that a number of technologies were extremely similar and were therefore grouped together in this paper.

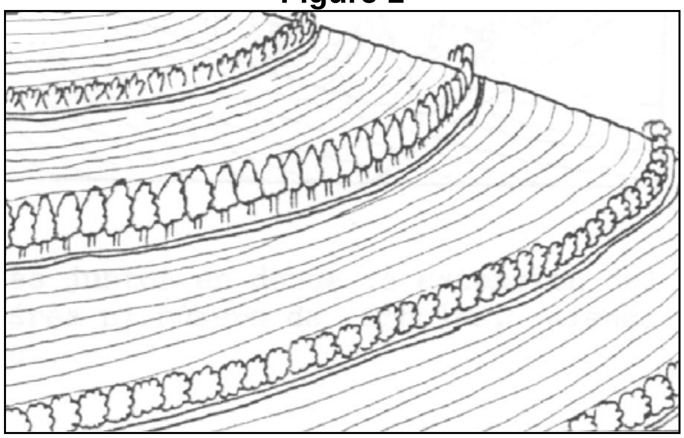
Resource conservation

1. ***Control of water erosion***

Rows in contour (bands along the slope)

A line of trees and/or shrubs whose location cuts the slope of the land leaving spaces called zones. They serve as a guide for cultivation along the slope (Figure 1).

Figure 1



Physical works

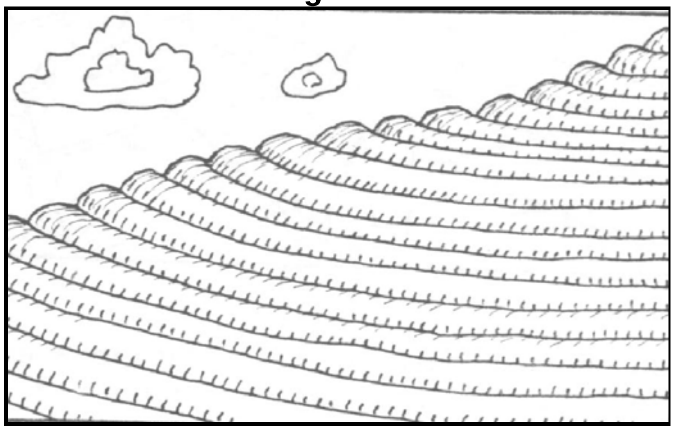
Actions taken to improve the topographical conditions of the land in order to minimize erosion and facilitate conservation. Labor and/or machines are used.

Furrows along the contour

Furrows that reduce runoff and improve infiltration, they serve to improve water utilization, facilitate conservation, and reduce erosion. Additionally, they serve as guide for cultivation and sowing of crops (Figure 2).

[17] Information on technologies can be obtained from Instituto Nacional de Reconstrucción Rural (1996).

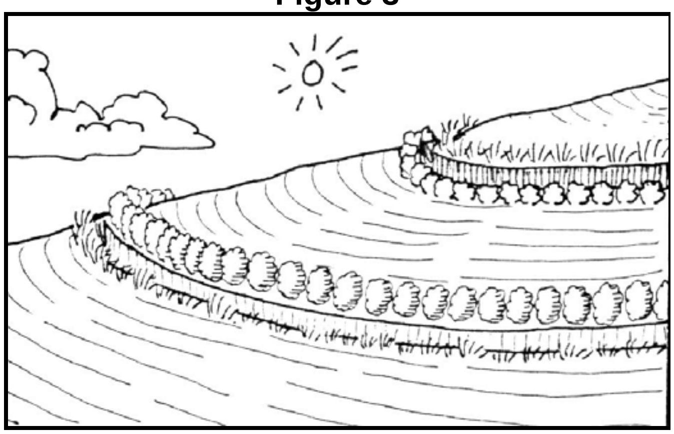
Figure 2



Water run-off channels

Channels created for the purpose of reducing runoff, improving infiltration, diverting excess water and contributing to the formation of slow-forming terraces (when combined with permanent vegetation). The channels are effective in slopes from 10 to 100% (Figure 3).

Figure 3



Contour interval

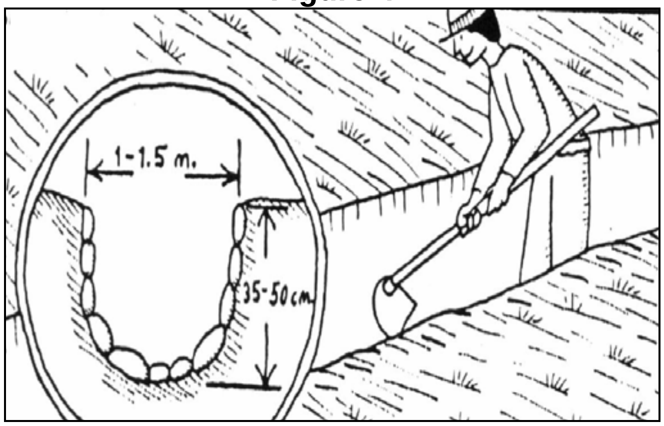
Similar to the furrows along the contour, they are uniformly spaced and are utilized in low precipitation areas.

2. ***Improved water management***

Irrigation canals

Canals for water delivery to parcels. Although the construction varies according to the type of soil, in general, construction in a parabolic shape is recommended since this resembles natural canals and requires less maintenance. The design consists of a semicircular bottom (parabola) whose dimensions vary according to the objectives, the technical requirements, and the availability of resources. If the slope is greater than 20%, then stones or cement are needed; if less than 20%, then pasture and grass provide sufficient protection. Dispersion "boxes" are recommended whenever there is a direction or slope change (Figure 4).

Figure 4



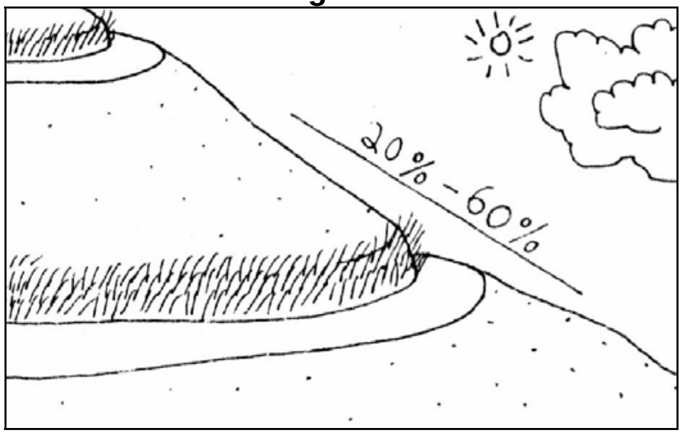
Reservoirs

Water tanks constructed with "soil-cement" (4 wheelbarrows of sifted soil mixed with a sack of cement), concrete, stone, or soil, constructed in accordance with the needs and physical condition of the soils. Its purpose is to store water for crop irrigation mainly during dry periods. Usually the soil structure in the communities is volcanic ash, which allows the construction of shallow, sunk reservoirs. The family constructs the tank often with the assistance of the community "minga" (labor exchange system).

3. ***Slow-forming terraces***

Terraces designed to develop over time that are constructed traverse to the slope. The terrace is developed through the accumulation of soil at the edge of the bed through the use of biological barriers and/or physical structures. The purpose of the terrace is to stop the erosion of the soils, to retain moisture, and improve land quality. The slow-forming terraces are formed within a period of three to five years. The distance between the terraces varies in accordance with the degree of the slope, type of soil, precipitation, and cropping system. This type of terrace is also known as terrace of successive formation. The cross section is made up of a margin in which there are no crops, but should be protected with permanent vegetation (Figure 5).

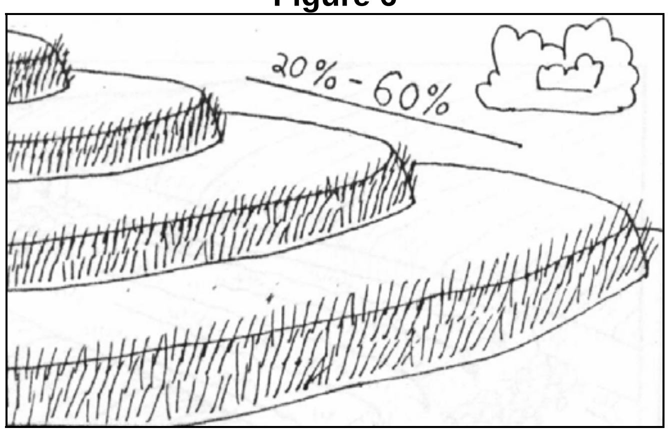
Figure 5



4. ***Bench terraces***

Moderately sloping or flat beds with banks constructed transverse to the slope of a land. Bench terraces require land removal and replacement for formation. The width of the bank varies with the slope, the depth and the type of soil. Vegetation and/or rocks are often used to maintain the terrace (Figure 6).

Figure 6



Agricultural intensification and diversification

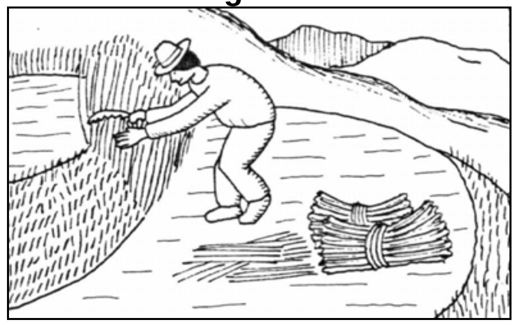
1. ***Biological barriers***

Bank protection

Planting pasture and grass, preferably perennials, on the bank of a terrace. The maintenance or management of grasses is simple but important and must be done in a manner that ensures that it functions well for slope protection and results in high yields. After sowing the grass, it is necessary to re-sow in places where gaps are observed to ensure coverage. When the grass has developed and has reached a height of 0.75 to 1.00 m it can be harvested. (Figure 7 and 8).

Figure 7

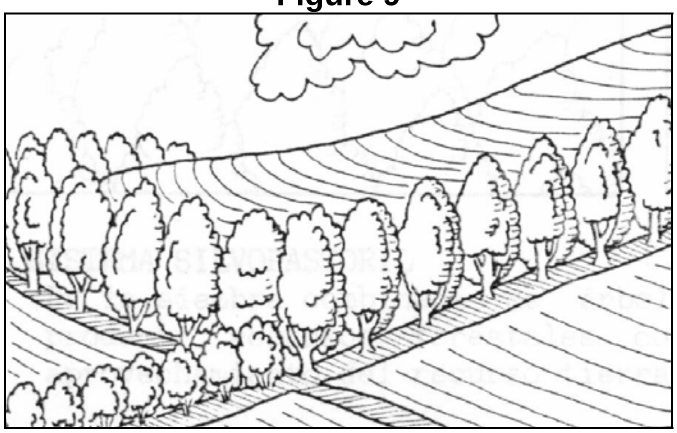
Figure 8



Pasture/Grass improvement
Improving pasture and grass management through enhancing the grass and legume association, improved cutting, dispersion of feces, fertilization, and irrigation (when it is available).

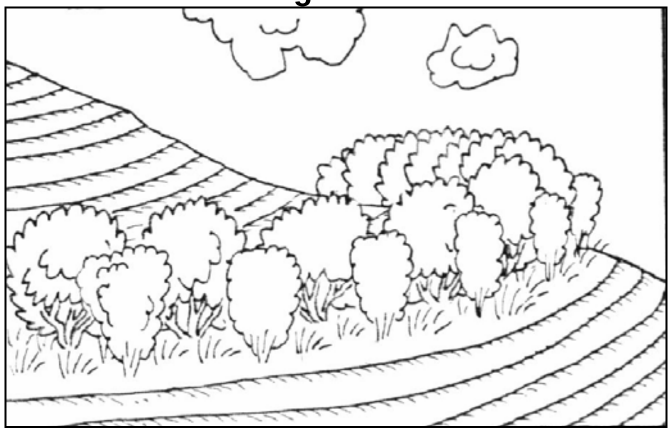
Hedge rows
Trees and/or shrubs planted along the margin of the lot or property in a manner that limits damages caused by wind, animals, etc. Species that offers most protection are suggested for use (Figure 9).

Figure 9



Live barriers
A dense zone (two or more rows) of trees, shrubs and grasses planted (preferably) with perennial plants that have well-developed roots, are formidable and have strong stalks. The purpose of planting the barriers is to reduce erosion and allow the development of slow-forming terraces. They can also be planted to reinforce physical works (Figure 10).

Figure 10

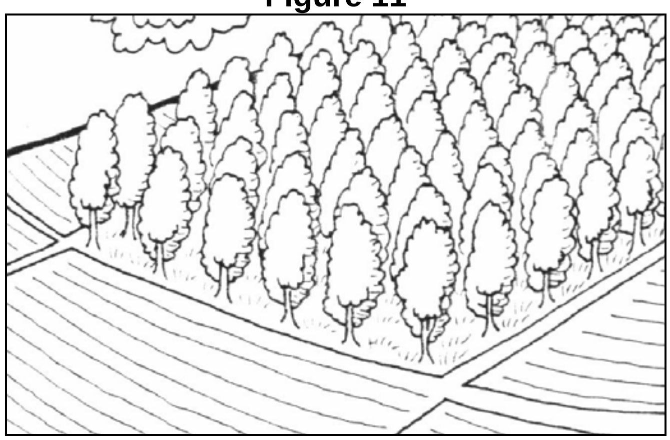


2. ***Agroforestry***

Small forests

Plantations of trees covering an area large enough to permit planting of a large number of trees (up to 250 trees). The spacing of the trees depends on the species planted. The trees reduce erosion and are eventually harvested, preferably in a sustainable manner (Figure 11).

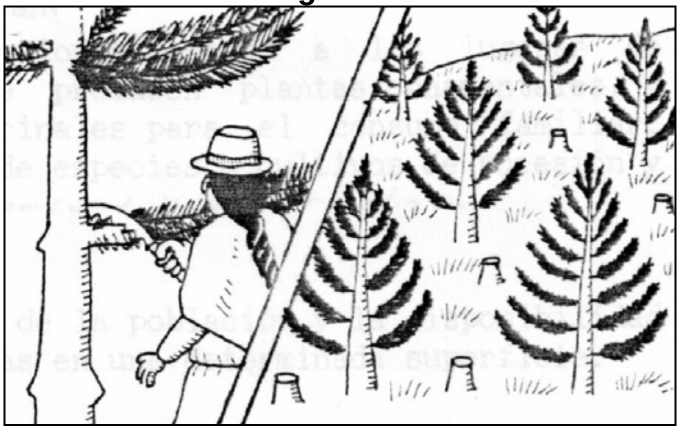
Figure 11



Agroforestry

Tree plantations or shrubs planted in combination with crops in order to obtain multiple cross benefits. Management of the plantations includes trimming of branches and roots and spacing appropriately to optimize the system (Figure 12).

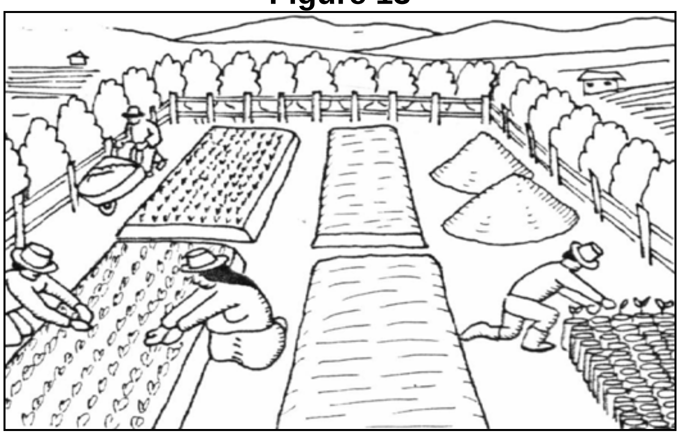
Figure 12



Nurseries

Nurseries designed for the production of seedlings for trees or grasses. These are usually community or group managed and done using basic technologies. The purpose is to allow the planting of forests, live barriers, etc. (Figure 13).

Figure 13



3. ***Soil quality improvements***

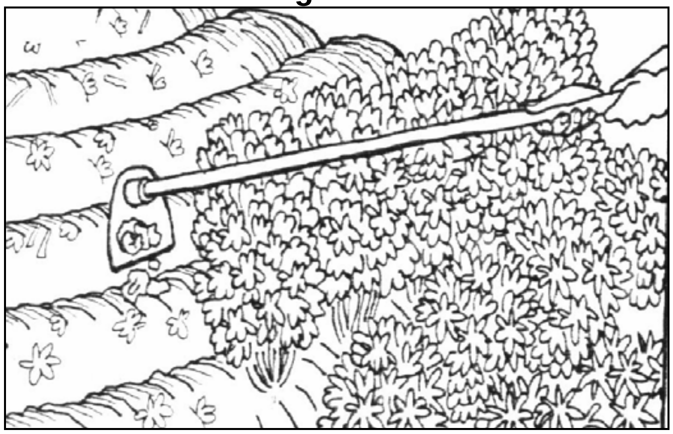
Worm culture

The intensive cultivation of earthworms for the purpose of transforming plant and animal waste into humus that is rich in microorganisms. The Californian red earthworm (*Eisenia foetida*) is used.

Fertilization with organic matter

Reintegrating plants near their physiological maturity into the soil. Legumes and grasses are usually used because of their high content of nitrogen and rapid decomposition. This improves soil structure and texture (Figure 14).

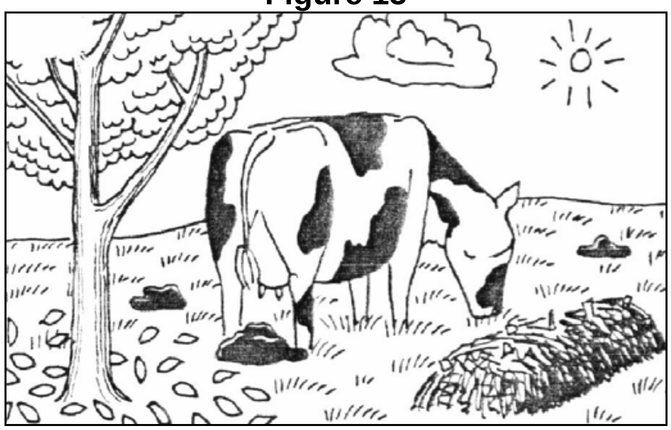
Figure 14



Composting

The decomposition of organic matter, particularly the residues of plants and animal wastes, for use as fertilizer. Once decomposed, it is incorporated into the soil to provide nutrients for crops (Figure 15).

Figure 15



4. ***Agricultural diversification***

Family plots (vegetable gardens)

A small plot of land, usually close to the farmer's house, where vegetables, fruit trees, medicinal or ornamental plants are grown for household consumption and/or sale in the local market. The plot contains a number of crops that often interact in a symbiotic manner (Figure 16).

Figure 16

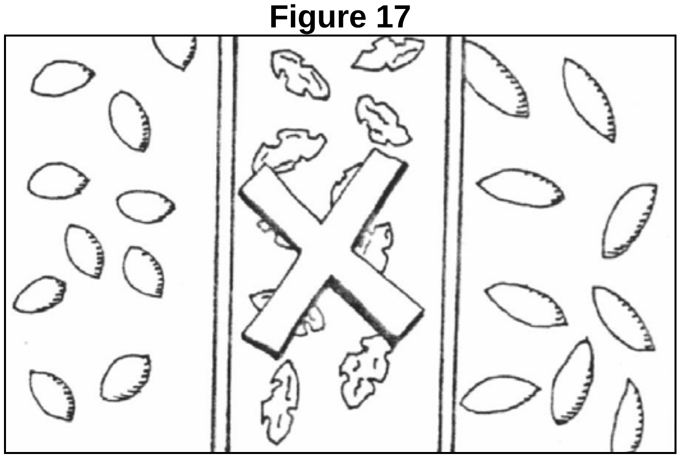
Fruit tree seeding
Actions taken to plant and construct terraces for fruit trees. The terraces are made exclusively for the fruit orchards and can be formed on slopes of up to 60%. Terraces for fruit trees are usually fairly narrow (around 2.00 m in width).

Greenhouses
Greenhouses made with wood from eucalyptus trees and covered with plastic. The ceiling is built at an angle and is up to 20 m. in length and 5 m. in width. They are mainly constructed to cultivate tomato and babaco. The greenhouses provide a better climate (temperature) for production, limit environmental pollution, and reduce the vegetative cycle.

5. ***Improved agriculture***
Crop improvement
Various activities that improve crop production.

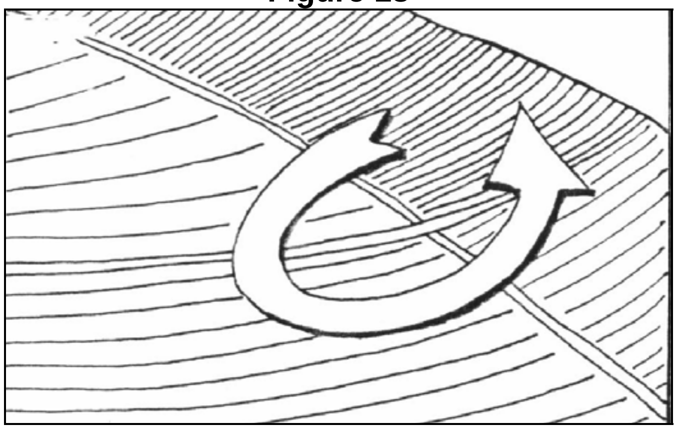
Seed selection and disinfection
Consists of selecting seeds free from pests, diseases and physical damage and application of chemical pesticides or natural products to eliminate remaining problems. This process provides the optimal conditions for crop production (Figure 17).

Figure 17



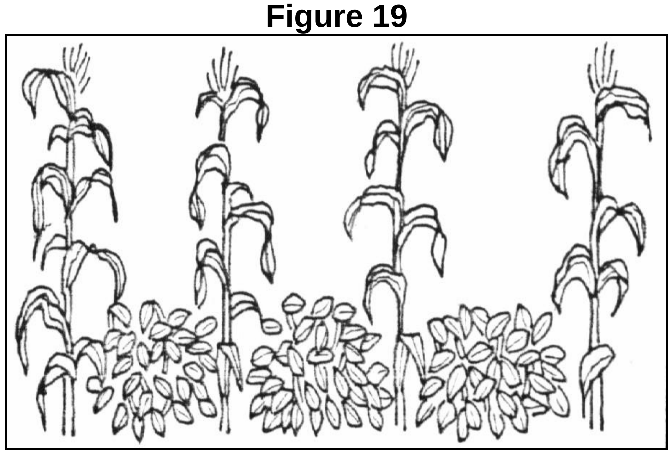
Crop rotation
Alternating the planting of crops across space and time in order to maintain the fertility of the soil and avoid the incidence of pests and diseases (Figure 18).

Figure 18



Crop association
Associating two or more crops such as a legume with a grass or a dense crop with a grain. This system can reduce erosion, maintain the fertility of the soil, and vary the food diet of the farmer (Figure 19).

Figure 19



Pest management
Practices recommended for control of pests and/or diseases. Recommended practices rely on information on the pest life cycle and population and try to minimize the effect of chemical use on the environment. An insect population is considered a problem when expected damage exceeds an economic threshold (Figure 20 and 21).

Figure 20

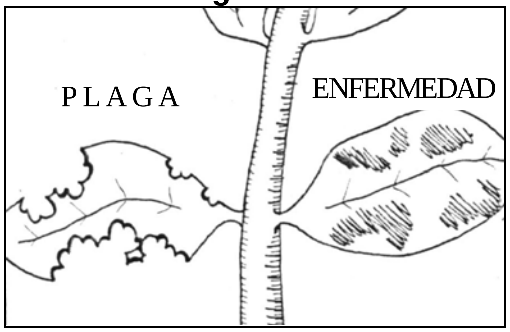
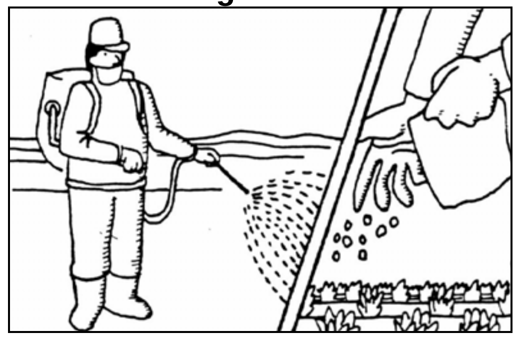


Figure 21



6. ***Improved animal management***

Management of small animals

Activities designed to improve production and utilization of the meat, skin and dung of guinea pigs, rabbits and birds.

Guinea pig pen

Raising of guinea pigs either for breeding stocks or for meat. Stalls of 1m x 1m with a height of 0.60 m are constructed and hold 10 females and 1 male. The stalls can be made of wood, cement or earth. The stalls are kept within a shed.

Fish farming

Farming of fish through the construction of a series of pools on the farmer's land. Trout are the primary fish being farmed.

Appendix 2. Specification of the probit on the terracing decision.

The probit on the decision to adopt terraces (Table 10) includes two dependent variables that may be considered endogenous. The decision to adopt biological barriers and new crops that diversify agriculture may be taken simultaneously with the decision to adopt terraces. If the decisions are simultaneous, then these variables may not be expected to vary independently of the other variables in the regression. To test whether the dependent variables in question vary independently, a test suggested by Hausman can be used (See Greene, 1997). The model is currently specified as follows:

Decision to terrace:

$$d^* = \beta' X + \alpha_B B + \alpha_D D + \varepsilon \text{ , } \varepsilon \sim N\left(0, \sigma_\varepsilon^2\right)$$

$$d = 1 \text{ if } d^* > 0,$$

$$d = 0 \text{ if } d^* \leq 0.$$

where: *X* = exogenous variables
B = presence of biological barriers
D = presence of diversified agriculture

The test of endogeneity involves regressing the potentially endogenous variables, *B* and *D*, on a set of explanatory (instrumental) variables to obtain predicted values for these variables, $\hat{B}$ and $\hat{D}$. The vectors of residuals, $\hat{\mu}_B = B - \hat{B}$ and $\hat{\mu}_D = D - \hat{D}$, are then calculated and included in the decision to terrace probit as follows:

$$d^* = \beta' X + \alpha_B B + \gamma_B \hat{\mu}_B + \alpha_D D + \gamma_D \hat{\mu}_D + \varepsilon \text{ , } \varepsilon \sim N\left(0, \sigma_\varepsilon^2\right)$$

$$d = 1 \text{ if } d^* > 0,$$

$$d = 0 \text{ if } d^* \leq 0.$$

If the null hypotheses that the coefficients on the residuals is equal to zero cannot be rejected (the standard test of significance) then, for the purpose of our regression, the variables *B* and *D* can be considered exogenous. If either null hypothesis can be rejected, then that variable cannot be considered exogenous. Table 13 presents the results for this regression. The tests of significance indicate that the null hypotheses cannot be rejected and the model is correctly specified in Table 10.

Table 13. Test of endogeneity.

	Coef.	test
Land characteristics		
Parcel size (hectares)	0.007	-0.27
Slope	0.003	2.84 ***
Altitude	-0.0008	-1.01
Human capital assets		
Male labor/ha.	0.012	1.76 *
Female labor/ha.	-0.012	-1.83 *
Age of head	-0.006	-1.14
Education level (ave. in HH)	0.077	1.92 *
Off-farm income (%)	0.003	1.08
Physical assets		
Value of animals owned (US$)	-0.00007	-0.08
Community characteristics		
Years community with CARE	0.114	2.27 **
Distance to city (pop>50,000)	-0.007	-1.26
Population density	0.231	2.86 ***
Rainfall	0.002	2.30 **
Complementary actions		
Agricultural diversification	-3.061	-1.22
Residuals for agric. diversification	3.487	1.38
Biological barriers	0.963	0.22
Residuals for biological barriers	-0.612	-0.14
Regions		
Azuay	0.225	0.17
Cañar	-1.290	-1.16
Chimborazo	-0.434	-0.36
Cotopaxi	0.954	1.41
Imbabura	-1.446	-1.49
Loja	-0.873	1.04
Constant	-0.413	-0.26

*= significant at 90%, **= significant at 95%, ***=significant at 99% level .