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NATURAL RESOURCES SYSTEMS PROGRAMME

FINAL TECHNICAL REPORT

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R6621

Project title

Strategies for improved soil and water conservation practices in hillside production systems in the Andean valleys of Bolivia

Project leader

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Organisation

Silsoe Research Institute

NRSP Production System

Hillsides

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ACRONYMS

CIAL	*Comité de Investigación Agrícola Local*
CIAT	*Centro Investigación Agrícola Tropical*
CIDETI	*Comité Interinstitutional para el desarrolo de Tiraque*
CIPCA	*Centro de Investigación y Promoción del Campesinado*
Cuenca	Catchment (or watershed)
DFID	UK Government Department for International Development
EU	European Union
EUROSEM	European soil erosion model
FAO	Food and Agricultural Organisation of the United Nations
FORCIAT	Proyecto de Fortalecimiento Institucional- CIAT
Municipio	Regional Municipalities
NGO	Non Government Organisation
OTB	District Level Development Committees
PRA	Participatory rural appraisal
PRODEVAT	*Programa de Desarrollo de los Valles de Arque Tapcarí*, Bolivia
PROINPA	Andean Crops Research and Development Foundation
PROMIC	*Programa Manejo Integral de Cuencas*
PTD	Participatory technology development
Sindicato	Committee representing the community
SRI	Silsoe Research Institute
SWC	Soil and water conservation
UMSS	*Universidad Mayor de San Simón*
UoR	University of Reading

FINAL TECHNICAL REPORT - R6621
Strategies for improved soil and water conservation practices in hillside production systems in the Andean valleys of Bolivia

Contents

Strategies for improved soil and water conservation practices in hillside production systems in the Andean valleys of Bolivia

Executice Summary

The project has contributed to its Goal (*Soil erosion and deforestation processes controlled)* and Purpose *(Economically viable land soil and water management practices packaged and promoted)* through delivery of the following Outputs:

Outputs:

i) An assessment of the potential for adoption of improved soil and water conservation practices indicated that a number of pre-conditions need to be met before adoption is considered. These include farmers recognising land degradation problems, security of tenure and profitability of farming as well as viable soil and water conservation (SWC) alternatives supported by efficient extension and communication systems.

ii) An assessment of the effectiveness of live-barriers and cover crops species in improving soil and water conservation indicates that grass species (in particular *Phalaris)* provide effective soil loss prevention, but that irrigation or high rainfall conditions are required to ensure rapid establishment. Without irrigation and with low rainfall live-barriers are unsuitable. Of the various cover crops tested *Tarwi* provided the greatest biomass with potential to provide the greatest yield increases for subsequent crops.

iii) The development of a hillsides system soil and water model based on the use of EUROSEM can be used to run through scenarios of different soil conservation measures or climatic regimes in a relatively short time. The model was validated in one of the Project's catchments (Pairumani).

iv) Social and economic evaluation of the vegetative soil and water conservation practices indicated viability and potential for adoption of grass species as live barriers in the more intensive cropping systems especially where there was additional benefit of fodder production. In less intensive systems they are less viable and less likely to be adopted. We consider that insufficient information is yet available on productivity increases arising from the use of cover crops and no economic evaluation was undertaken. This requires further evaluation.

v) Dissemination of the research results has been undertaken through distribution of three project workshop proceedings, 18 refereed papers with high quality extension material aimed at NG0s and farmers. The involvement of key stakeholders throughout the project cycle has promoted uptake.

Activities

The Outputs have been achieved through the following activities:

i) Information review and participatory rural appraisal of six communities in hillside areas of Cochabamba and Santa Cruz Departments. These identified existing farming systems, characterised farmers, identified major constraints and identified farmer attitudes towards natural resource management, particularly soil and water management.

ii) A biophysical characterisation of typical catchment areas in these locations showed the highly heterogeneous nature of the sub-Andean mountains ranging from semi-arid valleys to areas of cloud forest. They are densely populated in places and characterised by emigration and land degradation.

iii) Selection of species and field evaluations were undertaken using participatory research methodologies for both live-barriers and leguminous cover crops. This involved a combination of researcher and farmer managed experimentation with species selection based on survivability, adaptation to the local environment, suitability of growth habit for use as live-barriers, biomass production and potential economic benefits.

iv) Use of simulation models for assessing soil erosion and suitability of different legume crops. EUROSEM was used to assess the effectiveness of live-barriers for soil erosion control, using the model to scale up from a plot scale to a three hectare catchment. A crop/climate model was used to identify leguminous cover crop species for field testing different varieties of cover crops in the different agroecological zones identified.

v) Local communities were involved in a participatory technology development process through out the project with their criteria and valuations of costs and benefits being key in evaluating the technologies.

vi) Project workshops, development of extension material and involvement of key stakeholders during the project have played a major role in ensuring the initiation of the diffusion of the research Outputs

3 Contribution of Outputs to Project Goal:

The use of live-barriers has been shown to both increase productivity and control soil erosion at an individual plot or field level especially in the more intensive cropping systems, where live-barriers may encourage further intensification. Indications are that cover crops can play a significant role in this process and especially in soil fertility enhancement on stabilised hillsides. As such both can play a key role in improving livelihoods. Live-barriers are already being promoted by NG0s and initial adoption rates are encouraging. However, there is now a need for scaling up plot level activities to a wider landscape scale that will involve other natural resources user groups. As such it will be necessary to take into account potential conflicts as well as inter-community implications of watershed management. NG0s and community groups will require the appropriate skills to facilitate this.

1 BACKGROUND

Soil erosion and declining soil fertility are recognised as problems in the semi-arid valleys of the inter-Andean zone of South America, having a particularly strong impact on areas of subsistence agriculture and contributing to poverty inducing processes (Céspedes, 1998; Ellis-Jones, 1999). The mid-Andes area in particular, which includes Cochabamba and parts of Santa Cruz, is recognised as having extreme poverty in rural areas made worse by land degradation and low productivity. The areas between 1500-4000 masl are characterised by a multitude of microclimates and low productivity associated with soil erosion and declining soil fertility. The time that land is left in natural fallow has declined steadily as more land for crop production is required. There is, therefore, an opportunity for using live-barriers and leguminous cover crops to control erosion and improve soil fertility, increasing productivity and thereby reducing poverty.

The Project has been a collaborative research project between Silsoe Research Institute (SRI), UK, Cranfield University, UK, San Simón University (UMSS), Cochabamba, Bolivia, University of Reading, UK, and the Tropical Agriculture Research Centre (CIAT), Santa Cruz, Bolivia. The Project was initiated in August 1996 and was completed in September 1999, although dissemination of project outputs is has continuing

The Project worked in three Provinces in Santa Cruz and three in Cochabamba Department. The work concentrated on low-cost vegetative practices (live contour barriers and cover crops / green manures) and included the selection and evaluation of grass, shrub, and tree species for protective live-barriers; and legumes for fertility enhancement of the stabilised hillside soils. Technical and socio-economic evaluation of the options was undertaken primarily on the plots of individual farm families and with communities who were closely involved in evaluation.

The Project worked closely with complementary NRSP hillsides funded research projects in particular:

- *R6638 - Bolivia: Participatory technology development (University of Reading).* This project worked in the Santa Cruz area.
- *R6447 - Adaptability of cover crops (Bolivia, Honduras, Nepal, Uganda) (University of Reading).* In Bolivia this project identified potential cover crop species capable of germinating, flowering and setting seed within the growing season available, determined by temperature, photoperiod, and precipitation regime. Leguminous cover crops identified by this project were the subject of preliminary on-farm experimentation, which still requires further validation.

2 PROJECT PURPOSE

The project purpose was derived from Output I of NRSP Hillsides systems *(before revision)*, namely:

- **Economically viable land, soil and water management practices packaged and promoted.**

It did however contribute to two further Outputs, namely:

- Improved hillside cultivation techniques packaged and promoted, through collaboration with R6970 (improved draft animal management).
- Improved methods to maintain and enhance soil fertility packaged and promoted.

3 OUTPUTS

3.1 Determination of the potential for adoption of improved soil and water conservation technologies

More detailed information is available in Amado et al., 1998; Céspedes, 1997a, 1997b, 1997c, 1998; Ellis-Jones, 1999; Ellis-Jones and Mason, 1999; Lawrence et al, 1997; Mason, 1999.

Declining productivity due to land degradation remains a key issue in much of Cochabamba and Santa Cruz Departments. Before households consider conservation, a number of preconditions need to be met. Different communities have different perceptions of the causes and may not be willing or able to consider suitable SWC technologies due to a variety of reasons (Table 1).

Table 1. Preconditions necessary for household adoption of conservation measures

	Precondition		Reasons for non acceptance
1	Land degradation is recognised as a problem. **Yes**	**No**	- Very slow process, regarded as normal - More land readily available - Land not owned - Insecure future in farming
2	The *cause* of productivity decline is recognised **Yes**	**No**	- Other factors may be contributing to low productivity - Lack of knowledge - Land cultivated by others - Infrequent visits to land - Symptoms have appeared very recently
3	The household is aware of alternative soil and water conservation technologies that could reverse productivity declines. **Yes**	**No**	- Unaware of any technologies - Poor experience with development organisations - Inadequate extension - Poor information flow within the community
4	The household is willing and able to undertake conservation practices. **Yes..........................*possible ADOPTION***	**No**	- Need to secure food production in the short term - Insecure land tenure - Incompatibility with present farming system (grazing of live-barriers) - Insufficient labour - No access to inputs (seed etc.) - Poor financial return - Benefits are too long term - Other problems have higher priority

Source: Ellis-Jones and Mason, 1999

Conservation technologies are inherently different from other crop improvement technologies such as fertilisers, pesticides and improved seeds. Farmers would expect to see benefits from these within a cropping season. However, conservation measures usually involve significant initial and ongoing investment in cash and labour, with benefits only being realised in the longer term. Since the circumstances of poor farmers are often characterised by critical scarcity of assets, highest priority is usually placed on short-term benefits. Planning horizons are from one harvest to the next, or even from one operation to the next. This contrasts with the time horizon required for most conservation practices, where considerable investment of capital or labour is required before benefits accrue. A choice often has to be made between maximising present income and investing for future income. The attraction of receiving benefits within the first year of adoption is of major importance.

Traditional SWC practices including, *larkas* (contour cut-off ditches), *pircas* (stone walls as livestock barriers), *linderos* (vegetative barriers used as field boundaries), *jallmada* (ridges), *chaupirrayas* (intra-plot drainage canals), *aynoq'as* (fallows) and *atajados* (small dams for rain water harvesting and water storage) are used by some farmers (Amado *et al*., 1997) have quick pay-back periods (within the first year) and other functions outside that of soil conservation (acting as field boundaries, keeping livestock out, contributing to soil fertility or soil moisture improvements). Introduced measures such as *fanya juu*, contour stonewalls and bench terraces have not been widely adopted despite promotion by NGOs, unless subsidies are provided for their construction. (Richards and Escobar, 1995). This has implications for the adoption of improved SWC technologies, in that low costs, a need to provide short-term benefits and be multi-functional are important attributes. Live-barriers and cover crops have the potential for this.

3.2 Assessments of the effectiveness of appropriate live-barrier and cover crop species in improving soil and water conservation.

More detailed information is available in Sims et al.,1999, Sims y Rodriguez, 2000a; Sims y Rodriguez, 2000b; Sims y Villarroel, 2000; Sims et al., 2000a; Sims et al., 2000b.

Live-barriers

The Project has demonstrated the effectiveness of live-barriers for soil protection with a range of plant species and under a range of agro-climatic conditions (Table 2). *Phalaris* grass, previously unknown in the area, has proved to be particularly successful in areas of higher rainfall and where irrigation is available. It is effective in controlling soil erosion and provides valuable livestock fodder, which is usually cut and fed to both cattle and sheep. Other species especially vetiver have been as effective, but do not provide fodder. Bushes and trees alone have so far not proved to be as effective in controlling erosion as Phalaris, although the combination of Phalaris grass and broom, locally known as retama (*Spartium junceum)* has potential.

Table 2: Species suitability[1] for live barriers (√) showing farmer preferences (√̲) by agro-ecological zone, altitude (masl), rainfall and mean annual temperature.

Common name	Scientific name	Sub tropical valley 400-2900 630mm 19°C	Temporate valley 2900-3100 585-800mm 6-14°C	Valley head 3100-3350 592mm 14°C	Transition 3350-3650 531mm 9-11°C	Puna 3650-4200 585-800mm 6-14°C
			Grasses			
Vetiver	*Vetiveria zizaniodes*	√̲				
Phalaris	*Phalaris tuberoarundinacea*		√̲	√̲	√̲	
Brome	*Bromus catharticus*					√
Tall fescue	*Festuca arundinacae*		√	√	√	√
Love-grass	*Eragrostis curvula*	√̲	√̲	√	√	
Chilliwa*	*Festuca dolichophylla*		√	√	√	
Forage cane	*Sacharum oficinarum*	√̲				
Paja brava*	*Iru ichu*				√	√̲
			Trees/bushes			
Atriplex	*Atriplex halimus*		√	√	√	
Acacia	*Acacia dealbata*	√̲				
Kapa-kapa*	*Gynoxys oleifolia*					√
Kisuara*	*Buddleja coriacea*		√	√	√	√
Agave*	*Agave americana*		√	√		
Thola*	*Baccharis dracunulifolia*		√	√	√	
Muña *	*Satureja boliviana*			√	√	
Kewiña*	*Polyepsis incana*			√	√	√
Molle*	*Schinus molle*	√	√	√		
Broom	*Spartium junceum*		√̲	√̲	√	
Ceibo	*Erythrina facata*	√				
Chacatea*	*Dodonea viscosa*		√	√		
Algarrobo*	*Prosopsis juliflora*	√	√			
Chillca*	*Baccharis latifolia*	√	√	√		
Chamba	*Leucaena leucophala*	√				

* Local indigenous species

[1] Some overlap between agro-ecological zones occurs, dependent on temperature, rainfall and aspect.

Key indicators for successful barrier formation include.

- Barrier closure. Grasses have the potential to form barriers more quickly than shrub and tree species when these are planted alone and not in combination with a grass. Figure 1 shows the reduction in spacing between grass plants of vetiver and Phalaris with closure of grass barriers occurring between 9 and 11 months after planting.

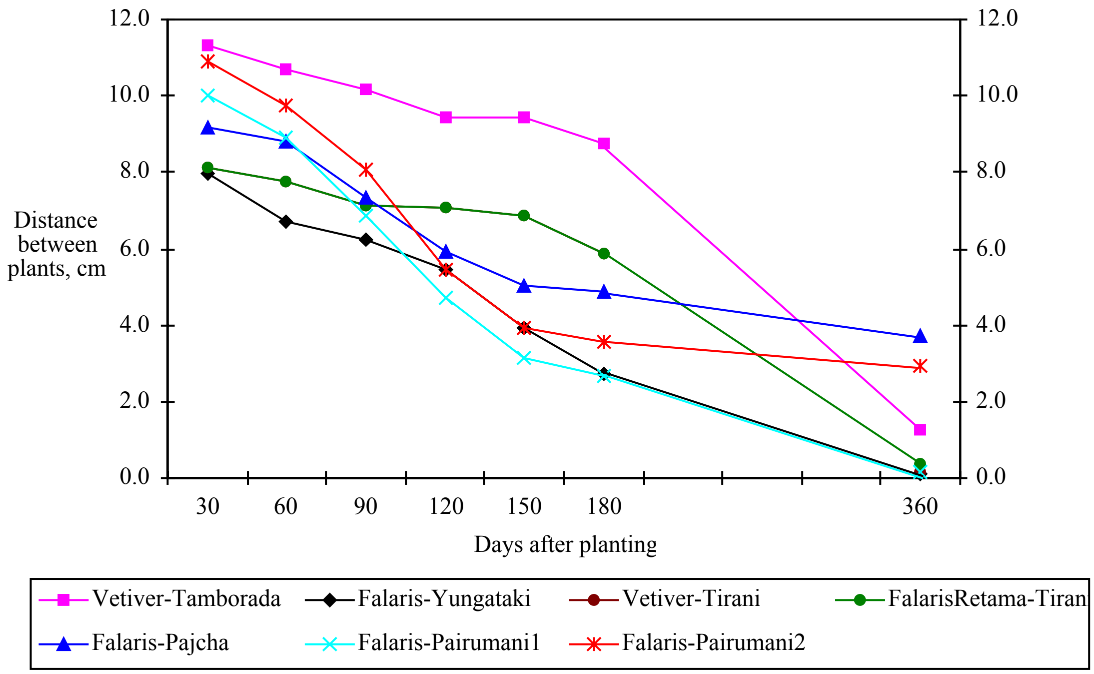


Figure 1: Reduction in spacing between grass plants with time

- Terrace formation, slope change and riser formation. Changes in micro-topography (slope, riser height and hence terrace formation) caused by the barriers were greatest in those areas with higher rainfall or irrigation. In drier areas, the tendency to form terraces was reduced. The intensity of tillage operations, soil erodibility and slope also affects riser formation. On 15-30% slopes terrace formation was promoted and where slopes are in excess of 30%, terrace formation is minimal.

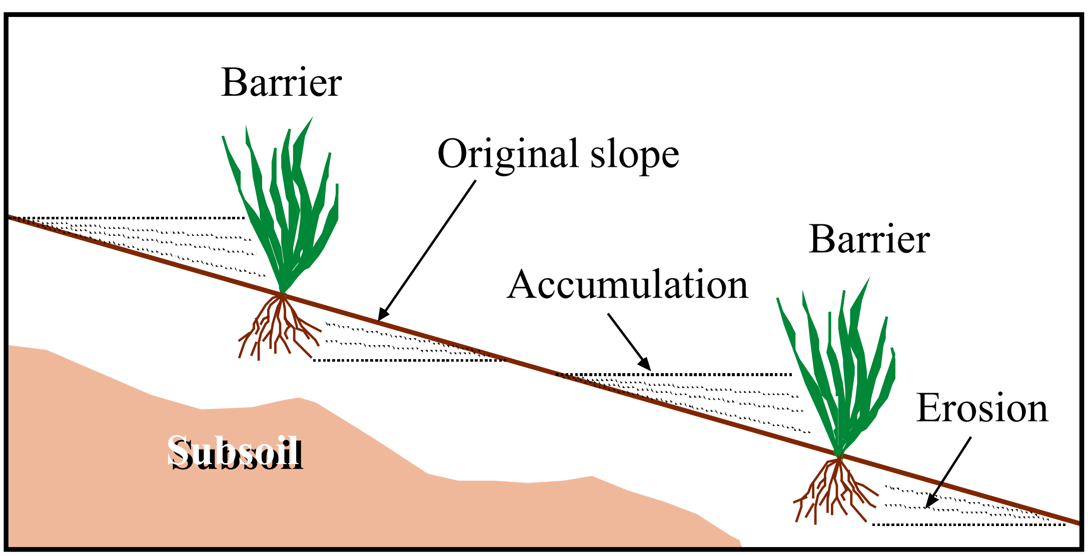


Figure 2: Changes in inter-barrier slope and riser formation with live-barriers

- Sedimentation and erosion. Live-barriers resulted in the deposition of soil above and erosion below the barrier (Figure 2) with most sedimentation found on plots as a result of soil tillage and irrigation.

- Biomass production. In Cochabamba, biomass production from the forage species, although highest for *Phalaris,* was highly variable, being greatest under higher rainfall or with irrigation. This varied from a low of 797 kg ha^{-1} in drier areas to a high of 2354 kg ha^{-1} per annum with irrigation. In Santa Cruz biomass after 180 days was highest for vetiver (2350 kg ha^{-1}), phalaris (1610 kg ha^{-1}), and forage cane (3945 kg ha^{-1}). From weeping love-grass it was 740. kg ha^{-1}

Cover crops / green manures

As a result of crop modelling[1] work, trials were established with planting Tarwi (*Lupinus mutabilis*), Garotilla (*Medicago polymorpha*), broad bean (*Vicia faba*) and Vetch (*Vicia sativa*) in combination with oats, comparing these to natural fallow regeneration (control). Two years of on-farm experimentation in three communities in Cochabamba (Table 3) established that Tarwi outperformed other legumes in reducing erosion, adding N and producing higher biomass, although vicia/oats mix gave highest overall biomass.

Table 3: Responses of legume species as green manures in three communities of Cochabamba

Species	Variable	Pairumani	Tirani	C.Jich'ana	*Mean*
Garrotilla	Cover, %	28	1	20	*21.3*
	Dry matter, kg/ha	878.9	226.9	194.8	*433.5*
	N added, kg/ha	32.5	8.4	7.2	*16*
	Erosion, t/ha	95.8	114.4	119.4	*109.9*
Broad bean	Cover, %	50	13	15	*26*
	Dry matter, kg/ha	1452.5	418.5	408.8	*759.9*
	N added, kg/ha	46.5	13.3	13	*24.2*
	Erosion, t/ha	126.5	116.8	88.9	*111.4*
Vicia/oats	Cover, %	61	1	27	*36.3*
	Dry matter, kg/ha	7092.2	803.1	485.2	*2793.5*
	N added, kg/ha	82.8	4.8	2.2	*29.9*
	Erosion, t/ha	263.5	161.3	75	*166.6*
Tarwi	Cover, %	16	40	39	*31.7*
	Dry matter, kg/ha	3152.2	2153.8	1718.8	*2341.6*
	N added, kg/ha	220.7	151.6	121	*164.4*
	Erosion, t/ha	81.6	52.1	45.7	*59.8*
Fallow	Cover, %	53	29	20	*34*
	Dry matter, kg/ha	853.1	380.1	39.1	*424.1*
	N added, kg/ha	-	-	-	-
	Erosion, t/ha	33.3	72.4	8.9	*38.2*
Mean	*Cover, %*	*41.6*	*23.8*	*24.2*	*29.9*
	Dry matter, kg/ha	*2685.8*	*796.5*	*569.3*	*1350.5*
	N added, kg/ha	*95.6*	*44.5*	*35.8*	*58.7*
	Erosion, t/ha	*120.5*	*103.4*	*67.6*	*97.2*

When vegetative cover was assessed at monthly intervals at Tirani (Figure 3), Tarwi gave the best cover (40%), followed by natural regeneration (26%) and the association vetch/oats (21%); followed by broad bean and garrotilla at under 15%. Water stress significantly affected the development of all species.

[1] This work identified legume cover crop species that are adapted to different altitudes within the Cochabamba region. Local researchers and NGOs may now concentrate their efforts on using a small number of adapted cover crops to counter the decline in soil fertility in the cropping systems of the Cochabamba region.

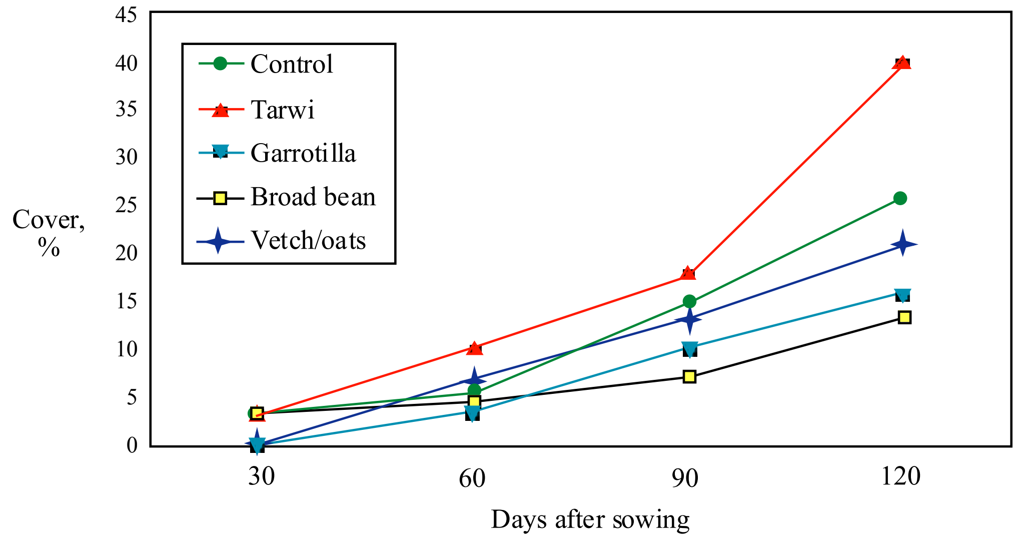


Figure 3: Vegetative cover of four legumes, Tirani, Cochabamba

Figure 4 demonstrates poor soil cover (<7%) at 30 days after sowing at the time of maximum precipitation and erodibility of the soil. High erosion rates at this time are a consequence of this with Tarwi providing the greatest protection.

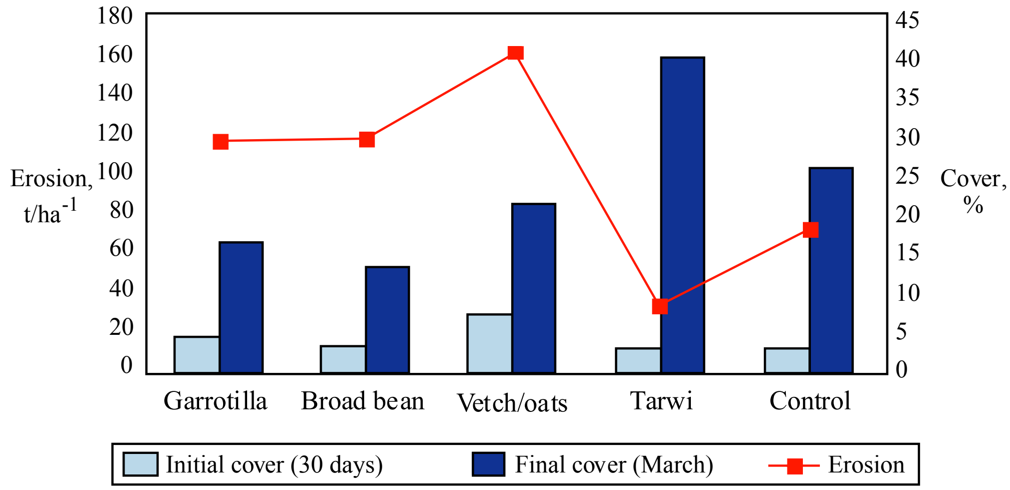


Figure 4: Relation between soil cover and erosion, Tirani, Cochabamba

Differences in biomass production were highly significant. Tarwi was the best ($p = 0.01$) producing 2154 kg ha^{-1}. This is due to its adaptability and robustness in supporting adverse climatic conditions. Broad bean, vetch, and garrotilla all had low production, as they are more susceptible to moisture stress and low soil fertility. Tarwi also contributed the greatest amount of N to the soil (152 kg ha^{-1}). All C:N ratios are less than or equal to 10 indicating rapid decomposition of the vegetation in the soil.

The effect of green manures on the subsequent crop productivity can be evaluated as a function of the biomass incorporated, N added and erosion reduced. However the effects are not realised in a single cropping cycle and it would be desirable to measure the effects for two or more years. There was insufficient time in this project to evaluate this impact.

Management of legumes

Key aspects of green manure management that need to be considered include:

- The vegetative cycle of legume species should be as short as possible in allow fitting into the cropping cycles..
- Establishing optimum planting dates, which depend on soil moisture conditions.
- Identifying the optimum time and means for incorporation. This could be when the plants have achieved 50% flowering or after some harvest of crop (as with broad beans).

3.3 Development of a hillsides systems soil and water model

For more information see Quinton and Rodriguez, 1999.

A process-based model (EUROSEM) was used to simulate the likely impact of live barriers on catchment wide soil erosion rates. However, scarcity of climatic data[2] to evaluate the model's performances makes it difficult to associate high levels of confidence in the absolute values generated by the model. The model has produced results in the right order of magnitude and has illustrated the impacts of soil conservation measures on soil erosion within a catchment in broad terms. Results can be viewed as indicators of response providing estimates of the likely magnitude of soil loss within the micro-catchment. Where the objective is to show exactly how much sediment is being eroded from a particular field then using EUROSEM, in situations where only limited information is available, will not produce results in which much confidence can be placed.

However EUROSEM can be an important tool in land use planning providing opportunity to run through scenarios of different soil conservation measures or climatic regimes in a relatively short space of time. Maps providing estimates of erosion losses for a number of scenarios can be produced at a variety of scales and these have the potential to influence local decision-makers e.g. farmers or local politicians. It has even been suggested (Ashby, personal communication) that process based models with a suitable interface might make a useful extension tool, allowing farmers and extension workers can work together to evaluate different erosion control strategies.

At the scientific level there is much to gain from applying models, such as EUROSEM, to micro-catchments. Process based models force us to think in a structured way about the processes we work with and challenge us to improve our understanding. Even with all the shortcomings of the evaluation of EUROSEM in this project, it has highlighted the need to improve the description of water flows through a semi-permeable barrier, such as a contour grass strip. At present EUROSEM is not able to simulate ponding of water and sediment deposition upslope of the live barrier. New algorithms describing the ponding of water will be required for EUROSEM to describe such situations in the future.

3.4 Economic evaluation of improved SWC technologies using farmer's evaluation criteria

For more information see Ellis-Jones et al., 1997; Ellis-Jones and Mason, 1999, Sims and Ellis-Jones, 2000.

The economic evaluation of the technologies has been based on farmers' criteria and valuation of costs and benefits actually faced by farmers. The methodology is based on an investment appraisal (cost-benefit analysis) described in Ellis-Jones and Mason 1999, Sims *et al*., (1999), which use a similar approach as outlined in Clark, Durón and Stocking (1998), being the methodology used/developed in Sri Lanka and tested under Bolivian conditions. The use of a partial budget approach to the evaluation of investments where costs and benefits accrue over a number of years and may involve an intensification of the farming system is not appropriate and was not undertaken.

Early evaluation of the conservation technologies (Ellis-Jones *et al.*, 1997a) concluded that none of the technologies was likely to be viable unless a substantial increase in productivity results. SWC technologies are only likely to be viable in the more intensive farming systems and are unlikely to be adopted by the resource poorest. In less intensive systems especially where irrigation is not available, adoption is likely to be low. Now that the technical performance of the barriers has now become apparent (Sims *et al.*, 1999 and Rodriguez, 1998) providing a clear definition of which species are best adapted to each agro-ecological zone, their performance in economic terms remains less clear as productivity gains in the short term remain highly variable.

Costs

In order to increase the attractiveness of the barriers, initial costs need to be low, which requires increased availability of planting material and reduced labour input. This can be achieved through gradual barrier establishment over a number of years as labour and planting is available, with maintenance undertaken

[2] Mountain environments rarely have dense networks of recording rain gauges or gauged catchments to provide the base data.

during off-peak labour demand periods. There are promising indications that costs are being reduced, *Phalaris* nurseries are being established, and NGOs are promoting the technologies. Adoption is apparent in a number of locations outside the project.

Benefits
In Year 1 (1996/97) no productivity differences were apparent with the live-barriers. In Year 2 (1997/98) all crops were badly affected by drought and yield differences were minimal but by Year 3 (1998/99) some differences began to emerge. Crop productivity based on yields and gross margins achieved by participating farmers over the three years of the project with extrapolations based on these and typical rotations found in each agro-ecological zone. A measure of intensification of crop rotations was also assumed when live-barriers are used.

Investment appraisal
A detailed cost benefit analysis of *Phalaris* (considered the most attractive species by farmers) was carried out for each agro-ecological zone with and without irrigation, attributing either zero or high value to fodder (Table 4). Net Present values at a discount rate of 20% have been used to assess viability. Key factors affecting the economic viability used in a sensitivity analysis are:

- Costs of establishment and maintenance, which are affected by the land area taken up by conservation, planting density and the distance between barriers and the width of the barriers affected.
- The yield and value of fodder from the live-barriers.
- Intensity of crop rotations, crop productivity, and possible increases in productivity as a result of using the barriers.

Table 4: Net present values of Phalaris live-barriers with and without live-barriers[1]

Zone	**Crop productivity increase**				
	0%	**3%**	**5%**	**10%**	**15%**
With irrigation					
Fodder value	**Zero**				
Valley	-90	-19	29	149	268
Valley head	-102	-13	47	195	344
Transition	-67	-30	-6	55	116
Puna	-93	-17	33	159	284
Fodder value	**High**				
Valley	44	112	160	280	399
Valley head	95	185	243	392	540
Transition	326	363	387	448	509
Puna	38	114	164	289	415
Without irrigation					
Value of fodder	**Zero**				
Valley	-73	-27	4	81	158
Valley head	-167	-36	51	269	487
Transition	-56	-35	-21	14	49
Puna	-57	-35	-20	17	53
Value of fodder	**High**				
Valley	-44	3	3	110	187
Valley head	-61	70	70	375	593
Transition	-12	11	11	58	93
Puna	-28	-4	-4	46	83

[1] At a 20% discount rate

Results indicate that:

X At a 0% and 3% productivity increase (with or without irrigation and low value of fodder), live barriers are not viable and unlikely to be adopted. At a high fodder value they are viable, indicating the great importance of the fodder.

X At a 5% productivity increase (without irrigation), live barriers are becoming viable even with a low fodder value, though not in the more extensive farming systems found in the *Puna* and *Transition*. With irrigation and high fodder value, *Phalaris* looks increasingly viable.

X At a 10% and 15% productivity increase, viability is achieved in all cases.

At a 5% discount rate viability is greatly improved. However a low discount rate is not considered to adequately reflect farmers' time preferences (Ellis-Jones and Mason, 1999).

Based on the assumptions made live-barriers are viable and adoption is most likely where either irrigation is available or climatic conditions allow fast growth of the species. Farming system intensification as a result of live-barriers will greatly enhance viability. The fodder value of the live-barriers is particularly important in ensuring viability and encouraging adoption. High initial costs of the technology need to be reduced before unsubsidised adoption is likely to be considered in the extensive cropping systems of the *Puna* and *Transition*. In the more intensive cropping systems in the *Valley* and *Valley Head*, especially where irrigation is available, technologies are viable and conservation is likely to promote further intensification. The biomass produced by *Phalaris* make it particularly attractive as fodder for livestock and this is an important reason for its increasing use.

3.5 Dissemination of research results

A full list of all dissemination material is shown in Annex I. These have been targeted at different stakeholders and include:

Research and development professionals in and outside Bolivia

- 20 refereed papers in national and regional (Spanish) and international (English) journals.
- 15 papers given at Conferences or workshops in Latin America, USA and UK.

Project stakeholders

- 4 Project workshops were held at which 60 papers were presented on project Outputs and related topics. Proceedings were produced and distributed from all of these.
- 18 technical reports.

NGOs and extension and development personnel

- 9 extension leaflets have been prepared and are presently in use by NGOs in Bolivia and other Spanish speaking countries.
- 3 manuals have been prepared in Spanish, one on the use of EUROSEM, one on the use of Map Maker software for GIS use and a third recently completed on research procedures and management.
- A course on hillside soil and water conservation was prepared for CIAT, Santa Cruz.

General public in Bolivia

- 6 newspapers articles on project activities.
- 1 video, which was shown on local TV and has been used for training purposes within UMSS.

Direct project participants

- 11 project working documents were distributed to the main investigators during the course of the project

In addition 21 student thesis have been completed, 14 at Agrónomo level, 5 at Master's level and 2 at technical college level.

The project has made a major contribution to the use of participatory research methods in the mid-Andes area of Bolivia, where research was generally top-down in nature. The University of San Simon now routinely uses participatory methodologies learnt from this project in other research and for undergraduate training. The project has acted as the focus for a number of other RNNRS-funded projects and has received an award by the Bolivian Institute of Agricultural Engineers (Colegio de Ingenerios Agrónomos de Bolivia) for major contribution to agricultural engineering research in the country.

4 RESEARCH ACTIVITIES

4.1 Output 1: Identification of indigenous soil and water conservation practices and the determination of the potential for adoption of improved technologies.

4.1.1 Information review and Participatory Rural Appraisals

Information review

Information was reviewed throughout the project in identifying economic and bioengineering attributes of vegetative species. This was carried out for the different agro-ecological zones predominant in the area with regional relevance. The work identified the degree of soil degradation in the area and the demand for R&D and diffusion in the area in the light of local knowledge and practices.

Participatory rural appraisals

Participatory rural appraisals (PRAs) were conducted in all project locations. These confirmed existing farming systems; characterised farmers; identified major constraints; identified farmer attitudes and perceptions towards natural resource management, particularly SWC. A review of existing SWC measures presently in use and identification of socio-economic and technical factors likely to prevent or promote adoption of improved technologies was undertaken. PRA reports on this include:

For Cochabamba

Cϑspedes E, 1997a. *CaracterPsticas tϑcnicas y socio-econ∴micas de la comunidad Yungataqui (punto de vista de los productores)*. Facultad de Ciencias AgrPcolas y Pecuarias "MartPn Cárdenas". Proyecto Laderas. Cochabamba, Bolivia.

Cϑspedes E, 1997b. *CaracterPsticas tϑcnicas y socio-econ∴micas de la comunidad Pairumani (punto de vista de los productores)*. Facultad de Ciencias AgrPcolas y Pecuarias "MartPn Cárdenas". Proyecto Laderas. Cochabamba, Bolivia.

Cϑspedes E, 1997c. *CaracterPsticas tϑcnicas y socio-econ∴micas de la comunidad Tirani (punto de vista de los productores)*. Facultad de Ciencias AgrPcolas y Pecuarias "MartPn Cardenas". Proyecto Laderas. Cochabamba, Bolivia.

Céspedes E, 1998. Sondeo inicial para identificar indicadores de la demanda de investigación en conservación de suelo y agua en los valles interandinos de Bolivia. *Revista de Agricultura*, Bolivia. 54(30): 3-7.

For Santa Cruz

Anon. 1997. *Diagnostico participativo sobre conservación de suelos en tres comunidades de los valles cruceños.* Proyecto Laderas. CIAT-SRI-ODA-Universidad de Reading. 30 p + anexos

Lawrence A, Eid M, Montenegro O and Sandoval E (1996). Mejoramiento participativo de conservación de suelos y agua en los valles Mesotérmicos, Santa Cruz. Universidad de Reading, Inglaterra, CIAT, Bolivia. 4 p.

Lawrence A, Eid M, Montenegro O and Sandoval E, 1997. *Participatory improvement of soil and water conservation in the temperate valleys of Santa Cruz, Bolivia.* Report on the diagnostic study and participatory research planning process. 103 p.

Key features of these PRAs were summarised by Ellis-Jones *et al*, (1997) and Céspedes(1998).

4.1.2 Characterisation of study areas

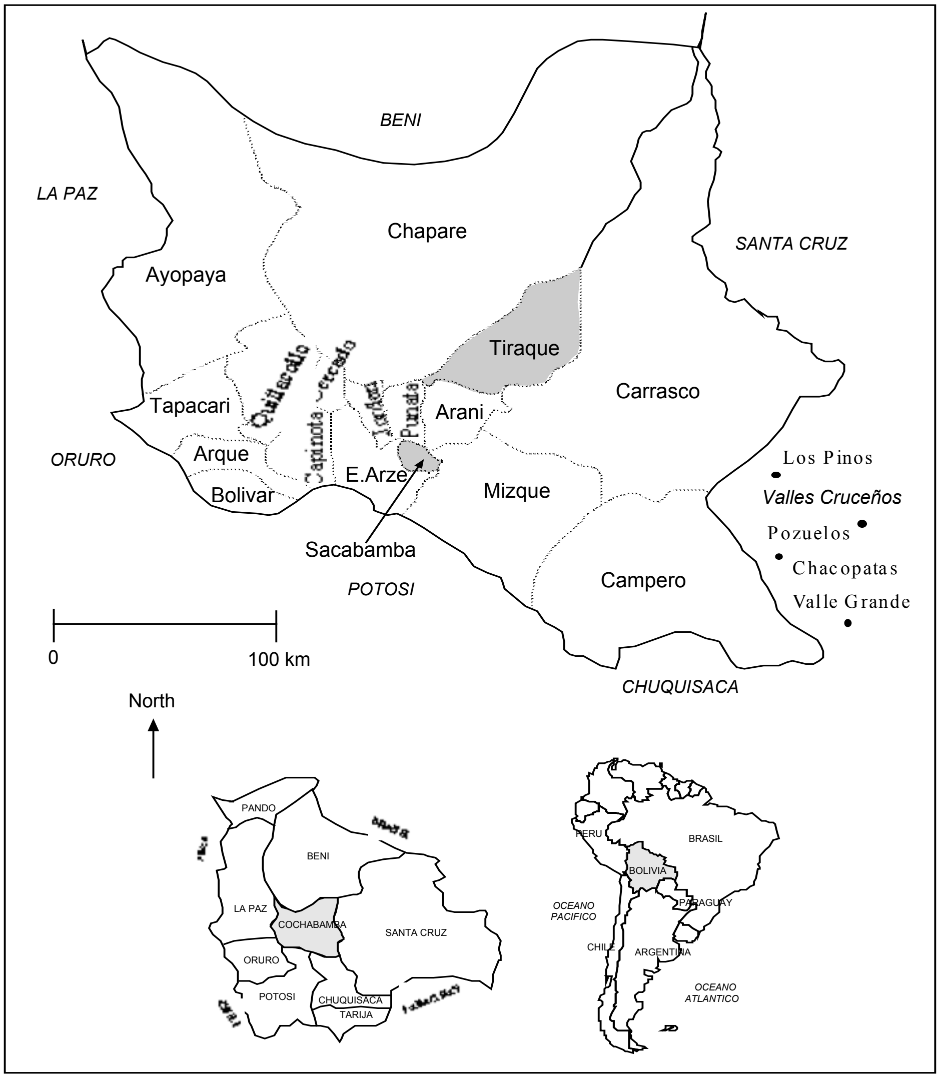
For more information see Espinoza, 1998; Coker 1998.

Agro-ecological zones were identified in terms of altitude, rainfall, soil type, slope, erosion hazard and existing land use (cropped land, grazing and forested areas) and existing erosion. Typical watersheds were characterised with the aid of aerial photography and Geographic Information Systems, both in terms of agro-ecology and in multi-temporal sequence to quantify changes in land use over time. The most important environmental characteristics are indicated in Table 5 where the experimental plots were established.

Table 5: Climatic characteristics of the Project sites,

Province	Community	Trial	Agro ecological zone	Altitude masl	Mean annual temperature °c	Annual mean rainfall mm
			Cochabamba (2500-4500 masl)			
Tiraque	Pairumani	5&6	Valley head	3300 - 3600	8	558
	Cebada Jich'ana	8	Transition	3400 - 3700	9-11	531
Esteban Arce	Yungataki	1&2	Closed valley	3300 - 3800	14	592
Cercado	Tirani	3&4	Valley head, Puna	2900 - 4500	6-14	585 - 800
	UMSS	7	Valley	2560	17	528
			Santa Cruz (1500-2800 masl)			
Valle grande	Chacopata	1&2	Valley	2840,2670		650
Caballero	Los Pinos	3&4	Transition	2600		550-700
Florida	Pozualos	5&6	Sub-tropical valley	1870	20	

Sources: CIPCA, 1997; CIDETI, 1994.



Map 1: Location of the main research areas

4.2 Output 2: Assessing the effectiveness of live-barriers and cover crops

4.2.1 Summary of research process

For more detailed description see Cespedes et al., 1998.

A summary of research activities in each community is shown in Table 6

Table 6: Summary of research activities in each community

Date	Activity	Cochabamba			Santa Cruz		
		Cebada Jich'ana	Pairumani	Yungataki	Chacopata	Los Pinos	Pozuelos
Nov 96	On-farm researcher managed trials initiated with live-barriers	X	X	X	X	X	X
Nov 97 to Nov 98	Farmers encouraged to experiment with live-barriers	X	X	X	X	X	X
Aug to-Sept 98	Workshops held in each community[2]				X	X	X
Dec 98 to Feb 99	On-farm researcher managed trials with cover crops established	X	X	X	X	X	X
Dec 98 to Feb 99	Farmers experiment with live-barriers and cover crops	X	X	X	X	X	X
May 99	Individual farmer discussions and farmer evaluation workshops	X	X	X	X	X	X

1 In Cebada Jich'ana work was undertaken in collaboration with PROINPA, who run the research station at Torolapa. Researcher managed trials were also undertaken in collaboration with PROMIC in Tirani.

2 Workshops were held in the Santa Cruz allowing farmers to evaluate trial results to date using matrix ranking techniques. This followed a workshop on participatory analysis and planning held in CIAT in May 1998 (Montenegro and Soruco, 1998). Similar workshops were not convened in Cochabamba, as a number of student theses used participatory methods to identify the most suitable species from a farmers' perspective (Céspedes, 1998).

4.2.2 Live-barriers

For more detail see Sims et al., 1999; Rodriguez, 1999; Wheeler et al., 1999.

At each experimental site various species of grasses, shrubs and trees were established to evaluate their performance as live-barriers[3]. Species planted in experimental and observation plots[4] both in Cochabamba and Santa Cruz are shown in Table 2.

The evaluation allowed appropriate establishment and management practices to be determined. Local researchers worked with NGOs who were already working with farmers' groups ensuring ready access to farmer groups and assisted in assuring active and willing participation in the on-farm experimentation programme. The following parameters were assessed for live barriers:

- *Measurement of erosion and sedimentation.* The effect of barriers on the retention of soil was measured with the help of permanent benchmarks above and below the barriers. Measurements were made to the soil surface from a taught cable tied to the benchmarks, the measurements indicate the accumulation or loss of soil before and after each annual rainy season.
- *Terrace formation, change of slope.* One of the effects of barrier establishment is the formation of terraces, annual measurements of slope of the inter-barrier soil will indicate changes in the micro-topography.
- *Plant development.* The following measurements were taken:

[3] Observation plots were also established in communities with a wider range of species not subject to the rigors of more formal experimentation

[4] Sims *et al.*, 1999, provides a detailed description of the experimental design.

For grasses: Height at approximately one-month intervals, rate of closure between plants, persistency and biomass production.

For trees: Height, width of crown, trunk diameter and persistency.

- Soil fertility and soil moisture. Although barriers retain soil within a plot, erosion still occurs between them. Soil sampling in the inter-barrier area did not indicate fertility gradients. However gradients are expected to form with time. Increased soil moisture above the barriers results in noticeably improved crop development especially in the dry years.

4.2.2 Leguminous cover crops (or green manures)

For more information see Wheeler et al., 1999

A crop/climate model was derived, validated, and run using six different cover crops with climate records for La Tamborada, Cochabamba (2600 masl), Zapata Rancho (3220m), and Toralapa (3490m) (Wheeler *et al.,*1999). This identified potential legume cover crops (Table 7), which can germinate; flower and set seed within a growing season constrained by temperature, photoperiod and rainfall patterns.

Table 7: Potential legume cover crops adapted to different altitudes near to Cochabamba.
(√ *indicates that a species is adapted for that sowing date)*

Location	Species	Sowing date					
		1 Nov	*11 Nov*	*21 Nov*	*1 Dec*	*11 Dec*	*21 Dec*
La Tamborada	*V. faba* (Bolivia)	√	√	√	√	√	√
2600 m	*V. faba* (Nepal)	√	√	√	√	√	√
	V. sativa	√	√	√	√	√	√
	V. dasycarpa	√	√	√	√	√	√
	T. resupinatum	√	√	√	√	√	√
	L. mutabilis	√	√	√	√	√	√
Zapata Rancho	*V. faba* (Bolivia)	√	√	√	√	√	√
3220 m	*V. faba* (Nepal)	√	√	√	√	√	√
	V. sativa	√					
	V. dasycarpa	√	√	√	√	√	√
	T. resupinatum	√	√	√			
	L. mutabilis	√	√				
Toralapa	*V. faba* (Bolivia)	√	√	√			
3490 m	*V. faba* (Nepal)	√					
	V. sativa						
	V. dasycarpa	√	√	√	√	√	√
	T. resupinatum						
	L. mutabilis						

The duration of growth varied between species and locations. All the cover crops investigated could reach maturity and provide seed from any sowing date at 2600m, and from most sowings at 3220m. However, cover crops adapted to 3490m were scarcer. Two cover crop species were adapted at the highest elevation. *V. faba* from Bolivia was predicted to reach first pod maturity when sown before 1 December, and *V. dasycarpa* was adapted from all sowings simulated. At elevations near to 3500m only *V. dasycarpa* and *V. faba* from Bolivia are potentially adapted. These two species plus L. mutabilis and V. faba from Nepal are potential cover crops for use at near to 3000m, and *T. resupinatum* and *V. sativa* are additional species with potential at the lowest elevations in the Cochabamba hillsides of about 2500 - 3000m.

The geographic range over which *V. faba* and *V. dasycarpa* were predicted to be adapted was investigated further from a sowing date of 1 December over the 1^o x 1^o area encompassing Cochabamba. The adaptation range of *V. faba* from Bolivia was far more extensive than that for species such as *V. sativa* and *T. resupinatum*. It was adapted to up to almost 3400m, some 52.0% of the area (Wheeler *et al*., 1999). *V. dasycarpa* was predicted to be adapted to the largest area of any of the species tested (and clearly has potential as a high elevation legume cover crop for the many of the highest elevations (>3500m) found in the Cochabamba area. There is a local need for fodder species adapted to these elevations. Therefore, the multipurpose use of *V. dasycarpa* as a cover crop and a fodder species is worthy of note.

As a result of this work, legume species with potential for use as cover crops were used in field trials (Table 8).

Table 8: Legumes[1] evaluated in Cochabamba and Santa Cruz

DEPARTMENT	SITE	SPECIES
Cochabamba	Pairumani, Tirani, Cebada Jich'ana	Broad bean (*Vicia faba* L.); Tarwi (*Lupinus mutabilis* Sweet); Common vetch (*Vicia sativa* L.); Garrotilla (*Medicago polymorpha* L.); association oats / vetch
Santa Cruz	Chacopata	Common vetch (*Vicia sativa*); Hairy vetch (*Vicia villosa*); Broad bean (*Vicia faba*); Tarwi (*Lupinus mutabilis*)
	Los Pinos	Common vetch;Hairy vetch; Broad bean; Tarwi
	Pozuelos	Glycine (*Neonotonia wightii*); Archer (*Macrotyloma axillare*); Lab-lab (*Dolichos lablab*); Forage groundnut (*Arachis pintoi*)

[1] *V. dasycarpa* was not included as seed was unavailable

In Cochabamba, randomised blocks with 7 m x 12 m plots and five treatments (broad bean, tarwi, common vetch, garrotilla, and a control) and three replicates for each of the three zones were established and the following undertaken.

- *Evaluation of soil N content.* Soil samples were taken monthly from upper, middle, and lower inter-barrier bands from crop planting to cover crop incorporation. The samples were analysed for Total Kjeldahl Nitrogen.
- *Crop cover.* Crop cover was estimated visually. A metal square of 1-m side is reticulated at 10-cm intervals with thin wire. Ground cover is estimated in each reticule giving values of 0% for bare soil, to 100% for complete cover. Measurements are taken monthly during the crop cycle, until incorporation.
- *Days to flowering.* This is the time for 50% of the population to show its first flower.
- *Dry matter yield.* Biomass production is measured at 75% flowering by taking measurements of fresh weight (kg m^{-2}) in 1 m^2 (pF), fresh weight of a sub-sample (pf) and the dry weight of the same sub-sample (ps). The dry matter (DM) is given by:

$$DM = pF \times (ps/pf)$$

- *Nitrogen content of plant tissue.* Legume plants were sampled and analyzed to determine the N content of material incorporated in the soil.

In Santa Cruz three legume trials were established (in Chacopata, Los Pinos and Pozuelos). The design was randomised blocks with four treatments (5 m x 5 m) and four replicates. In this primary phase the aim was to observe the adaptability of the legumes to the agro-climatic conditions and to learn the farm families' appreciation of the value and potential of the crops. The following data were recorded: growth rates; soil cover; days to 50% flowering, days to physiological maturity; biomass production and bromatological analysis of plant tissues.

Output 3: Simulation models (EUROSEM)

For more information see Quinton and Rodriguez, 1999

4.3 Simulation of the effects of live-barriers

Results from plot scale live-barrier studies in Cochabamba on the effectiveness of live barriers for soil erosion control were used to evaluate EUROSEM. The model was then applied to a three-ha micro-catchment, comprising 28 plots or fields of varying sizes and slopes (20-30%). The model was parameterized for the existing conditions using parameter values derived from field survey and from existing experiments in the area. A rainstorm, which would have a return period of five years in Cochabamba, was constructed and soil erosion and runoff dynamics were simulated in the catchment. Grass barrier strips were then introduced into the simulation, at a spacing of 9m and the simulation results compared. Results illustrate estimated reductions in soil erosion and of 185 kg at the catchment outlet and up to 1404 kg for individual fields within the catchment (Figure 5).

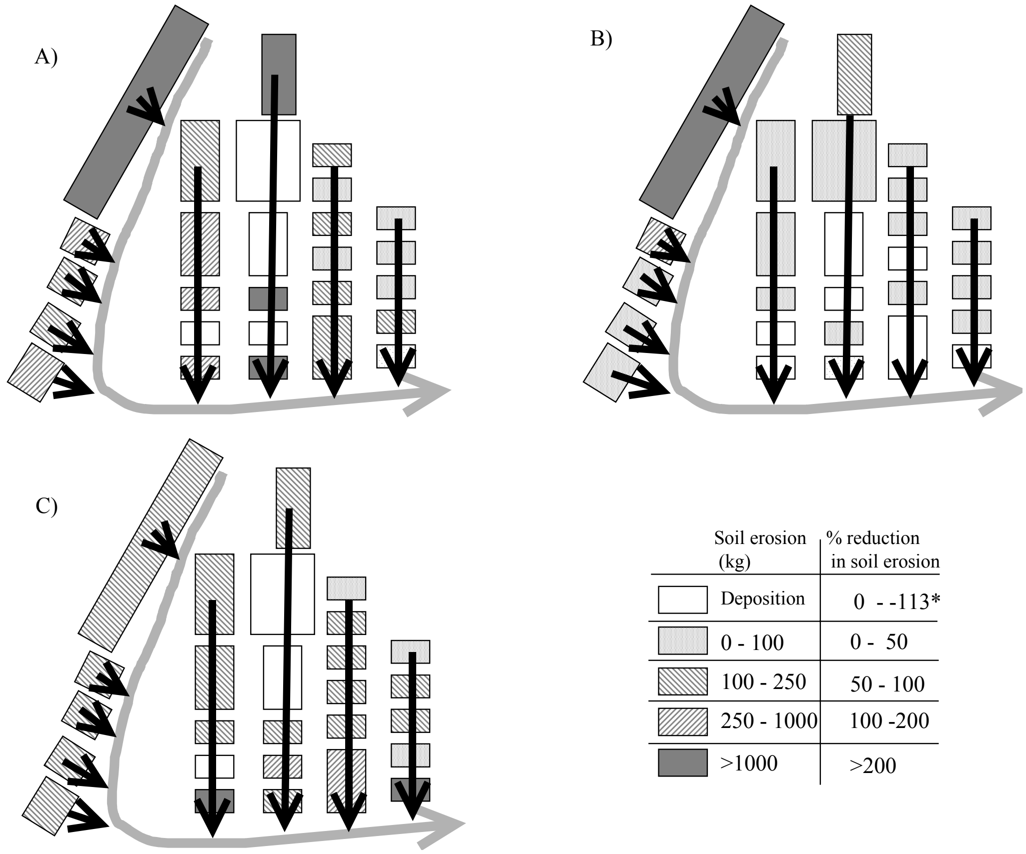


Figure5: Net soil loss (kg) on each catchment element from A) bare soil and B) with 1 m live barriers introduced at 9 m spacing, and C) the percentage reduction in net soil loss.
**Represents an increase in soil loss.*

Although most elements showed a reduction in estimated soil loss, four elements either produced more or deposited less sediment with live barriers. The reasons for this lie in the amounts of sediment being produced and the ability of the flow to entrap more material. In the bare condition sediment production rates are high and fill the transport capacity of the flow, at this point net deposition begins to occur, as any material eroded cannot be held in suspension. When the barriers are introduced sediment production rates are considerably lower and transport capacities are not reached, allowing small amounts of sediment to be eroded from each element. Where barriers are depositing less it is simply because less material has been eroded from the upslope elements.

4.4 Output 4: Socio-economic evaluation

4.4.1 Participatory evaluations

For greater detail see Sims and Bentley, 1998, Céspedes et al., 1998

The different locations of the Project used different levels of participatory research. In Santa Cruz methods adopted have been largely contractual (Biggs, 1989 cited by Okali *et al.*, 1994) in which the interested farmers provide land and labour. The design of the experiments, data recording and analysis, whilst discussed with the collaborators, were directed by scientists. In Cochabamba, where the Project has a bigger team, the style is largely consultative. Farmer collaborators give their land and labour and, furthermore, are involved in the design and management of the experiments. From the first year a programme of consultation with farmers in the three valley provinces of Santa Cruz was initiated in a complementary project (Lawrence *et al.*, 1997). To complement the process of participatory research, a series of community meetings were organised to discuss research results and promote experimentation with interested farmers. Courses and field demonstrations were arranged for NGO field technicians, extensionists, and interested farmers. Farmers have been encouraged observe the trial plots and to further experiment with those technologies they considered most suitable to their local conditions. A number of participatory evaluations were undertaken during the project after the end of each season and to assist in making preparations for the next (Montenegro and Soruco, 1998 in Santa Cruz; Hinojosa, 1998; Jaldin, 1998 in Cochabamba).

In Cochabamba, by Year 2 of the project it had become apparent that, throughout the District, *Phalaris* was the preferred live-barrier specie due to its rapid growth, ability to control soil erosion and it's fodder potential. Informal farmer managed experimentation began to spread in the second year. Community meetings and planting sessions enabled an increasing number of farmers to become involved with experimenting themselves. Seeing the success of the formal trials motivated many others. Modification and adaptation with changes in the farming system were apparent. Near the completion of the project, all communities were consulted in a final participatory evaluation (Céspedes *et al.*, 1998, involving:

- Individual and focus group discussions with farmers in each community.
- Discussions with key informants in each area to provide further insight to the problems faced and priorities for future research.

These explored:

- The relationship between formal and informal experimentation, the participatory development process, SWC technologies presently being used.
- Farmers' evaluation of technologies, modifications and adaptations to the technology and changes in farming system including the role of women in SWC.

Modifications and adaptations to the technology

Phalaris had a variety of alternative uses, reflecting the adaptability of the species and the innovativeness of farmers and NGOs promoting it. *Phalaris* use and live-barrier designs were often altered to suit the needs of the farming systems. Alternatives uses included:

- Growing it as a single species.
- Growing it in mixed species stands.
- Stabilising irrigation canals and protecting them from run-off debris thus reducing the labour required for cleaning.
- As field borders or *linderos.*
- Planted above stone-walls to improve structure stability.
- Planted on earth banks/terraces with fruit trees.
- Planted on their own as a fodder crop.
- Planted on the top of *Fanya juu* as a slope stabiliser (on the CIPCA irrigation scheme at Sacabamba).

Changes in farming systems

Although it was clearly too early to establish the impact of live barriers on the farming system, some changes were becoming apparent. These included:

- *Diversification of crops*. Higher value crops were being planted as soil fertility increases. Particular examples already include onions, tomatoes, and lettuces in Pairumani and flowers in Pajcha.
- *An increase in the value of land as productivity increases.* This is particularly so in the areas close to Cochabamba where land values have more than doubled (Meza, personal communication, 1999)
- *An increase in mixed cropping*- (maize, beans, legumes) and greater use of rotations.
- *Fodder being cut and carried to animals.* With livestock now being prevented from grazing in the arable areas, Phalaris was now being zero grazed. Feeding oxen in the fields as they are working is seen as a big advantage.
- *Improved livestock management* as a result of better fodder.
- *Decreased use of marginal land.* Some farmers expressed a desire to stop cultivating their steeper rainfed fields, perhaps planting them with phalaris or other suitable pasture specie. They would then use their irrigated fields more intensively.
- *Sale of plants* was seen as a possible additional source of income.

4.4.2 Economic analysis

For more information see Ellis-Jones and Mason, 1999, Sims et al., 2000.

The project explored those factors, which influenced household responses to soil and water conservation technologies, gaining an understanding of the effects of socio-economic variation on household decision making processes and establishing a framework for analysing these differences. This included an analysis of rural livelihood strategies, farming systems, and households' characteristics as ways of identifying recommendation domains. Although such methodologies remain theoretically useful, collection of the necessary field data was often problematic. Analysis of household decision-making based on semi-structured interviews and informal discussions provided the basis for economic analysis using the actual costs and benefits faced by farmers (Table 9).

Table 9: Farmers' perceptions of advantages and disadvantages of conservation technologies and the basis for their quantification

IMPACT OF CONSERVATION	BENEFITS AND COSTS
Farmers perceptions of advantages	**Quantification of benefits**
<u>*Direct benefits*</u> Increase in crop yields Reduced soil erosion Sediment trapped in field Other fields protected from storm damage Less work in repairing storm damage Material available for mulching or incorporation Increased soil moisture Increased soil organic matter Intensification of farming system Reduced incidence of pests and weeds Reduced labour for weeding	<u>*Productivity increase*</u> Increase in yields and their value less any increase or decrease in costs of production.
<u>*Indirect benefits*</u> Increased livestock fodder Firewood and building materials Fruit Shade in the fields	Value of additional fodder, wood, sticks, fruit etc.
Farmers' perceptions of disadvantages	**Quantification of costs**
Time taken for establishment and maintenance Limited effectiveness in first year Reduction in area for cropping Competition with crops for nutrients, soil moisture, and sunlight Increases incidence of pests and weeds	<u>*Establishment and maintenance*</u> Materials (Seed, plants, fertiliser, transport, fencing) Labour (skilled and unskilled) <u>*Loss of productivity on lost land*</u> Loss of gross margin with no conservation on area occupied by conservation

More detail and explanation of this is provided in Céspedes *et al*. (1998) and Ellis-Jones and Mason (1999)

Farmer identified criteria provided the basis for quantification of costs and benefits with emphasis placed in developing the methodology and using it for evaluation of live-barriers. Insufficient data were available to apply a similar approach to the use of cover crops, as little farmer testing of technologies had been undertaken[5] and evaluation criteria important to them had not been identified.

4.5 Output 5: Promotion activities

The major promotion activities included

- Annual Project Workshops (1996, 1997 and 1998), which provided a forum for stakeholders (farmers, researchers, NGOs, development projects, Government planners) to:
    - Undertake detailed planning of the project

[5] Evaluations undertaken based on this methodology but using assumptions not yet field tested have demonstrated the potential viability of cover crops.

  - Allow researchers to present results achieved at that time
  - Facilitate further discussion on soil management issues
- Community level workshops with NGOs, farmer-to farmer visits, practical training and conservation practices being installed on farmers' plots. The participatory research approaches involved whole communities and NGOs in evaluation of farmer experimentation.
- Collaboration with an EU-funded project (PRODEVAT in Cochabamba) led to diffusion of project outputs to a wider range of environments.
- Publications in local and international journals have ensured local and international scientists are aware of the project results.
- Farmer and NGO extension bulletins have promoted project outputs and are leading to wider adoption.
- A project video has been used in training workshops and by local TV channels

A full list of project publications is shown in Annex I.

5 Contribution of outputs

What further market studies need to be done?
Declining productivity, land degradation and poverty remains a concern in much of the mid-Andes. Different communities have different perceptions of the causes and may not be willing or able to consider suitable SWC technologies.. There is a clear need to identify which factors promote greater awareness of SWC and to target appropriate interventions towards individuals and communities who are in a position to adopt them. Methods for scaling up of the technologies developed by this project need to be investigated.

Economic analysis has shown that establishment and maintenance costs of SWC need to be low before unsubsidised adoption is considered. Productivity needs to be increased by at least 5% before they become viable. Since adoption is more likely through farmer-to-farmer communication, there is a need to encourage increased farmer experimentation with researchers facilitating and not controlling experimentation. This need not just include live-barriers and cover crops but other SWC techniques. Farmers' criteria are more important than researcher criteria in the economic evaluation of the experiments and more work is required on cover crop management.

How the outputs will be made available to intended users?
Project outputs have already been widely distributed internationally and within Bolivia. A number of refereed papers have been published and more are planned, courses run and extension material distributed during and after completion of the project. Three manuals have been produced to be used as training material.

A process of consultation with farm families accompanied experimental work. Interviews and rural workshops provided information on farmers' priorities confirming that live-barriers and leguminous cover crops were highly favoured. As a result, both UMSS and CIAT in conjunction with local NGOs have initiated a programme of promotion of these practices. In Cochabamba, funding from DFID-Bolivia has facilitated this.

What further stages will be needed to develop, test and establish manufacture of a product?
Although much of the work has been participatory in nature, involving NGOs, farmers and farmer groups, a new initiative is now needed, namely how to promote scaling up, how to involve all user groups, funding and facilitating organisations through the range of agro-ecological niches in a wider landscape scenario. This needs to consider the existing institutional structures and the relationships between them. Methodologies need to be developed to link individual and group level research with practical community level development. Inter-community implications of watershed management need consideration. The availability of external advice and support, through NGOs and rural development projects, is vital for the success of this process. Particular requirements include:

- Identification and development of methodologies for improving management of common property resources.

- Identification and promotion of improved cover crop management for the range of agro-ecological conditions.
- Development of processes for scaling up research results at a field level for community watershed management.

Although the promotion pathways to the target institutions and the farming community are theoretically in place, there remains a need to strengthen these to ensure that new knowledge is effectively disseminated.

How and by whom, will the further stages be carried out and paid for?
NRSP management has approved a proposal for this and implementation has been initiated.

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Annex II: Project Logical Framework

Appendix I: Project Logical Framework

PROJECT TITLE: Strategies for improved soil and water conservation practices incorporated into Hillside Production Systems in the Andean Valleys of Bolivia. **SHORT TITLE:** Bolivia: Hillsides, improved soil and water conservation practices			**PERIOD OF ODA FUNDING:** 1995/6 to 1998/99 **TOTAL ODA FUNDING: £ 311 107** DATE: **FILE REF:**
GOAL	**INDICATORS OF ACHIEVEMENT AND VALUE**	**HOW INDICATORS CAN BE QUANTIFIED OR ASSESSED**	**ASSUMPTIONS, RISKS AND CONDITIONS**
Soil erosion and deforestation processes controlled.	Improved land use/land management practices implemented by 2000 in target areas. By 2005 in target areas: - Soil erosion reduced by 25% - Rate of reafforestation increased by 25% - Biomass off take increased by 10%	National production statistics Reports of target institutions Research programme reports Evaluation of NRSP Monitoring against base line data	
PURPOSE			
Economically viable land, soil and water management practices packaged and promoted.	Field testing of techniques demonstrates capacity to reduce erosion by half Increased precipitation infiltrates soil or is otherwise effectively retained Soil moisture available for crop production increased	Research programme reports	Target institutions invest in the uptake and application of participatory research technologies. Enabling environment (policies, institutions, markets, incentives) for widespread adoption of new technologies and strategies exists Complementary research results on cover crops, soil fertility management systems, tillage methods and equipment and livestock nutrition and management is available
OUTPUTS			
Stage I 1 Identification of indigenous soil and water conservation practices and determination of the potential for adoption of improved technologies. Stage II 2 Assessment of the effectiveness of appropriate live barrier and cover crop species in improving soil and water conservation. 3 Development of a hillsides systems soil and water dynamics model. 4 Social and economic evaluation of improved soil and water conservation technologies using farmers' evaluation criteria. 5 Dissemination of research results through NGOs, publications, seminars, and extension material for extension agencies.	Stage I iNatural resource characterisation and PRAs completed in 2 study zones by October 1996. NGOs, projects and collaborator farmers participating with the Project by October 1996. Information review completed by October 1996. Stage II iIdentification of species for evaluation completed by November 1996. Design criteria for live barriers completed by 1999. Field evaluation completed by December 1998. Evaluation and validation of the models by March 1999. Socio-economic evaluations completed by December 1998. Validation of Sri Lanka model in Bolivia by March 1999. During 1996, a local workshop for farmers and NGOs held to plan farmer participatory research. Workshop Proceedings in 1996, 1997, and 1998 published. Extension and training material produced in 1998 in conjunction with NGOs. One scientific paper produced annually in 1997, 1998, and 1999. Distribution of manual on research procedures and guidelines for use of vegetative species in 1999.	Research reports, scientific papers Research reports, diagnostic survey results, scientific papers Project reports, students theses, scientific papers Socio-economic data, scientific papers Workshop proceedings, scientific papers, extension material	Collaborating institutions, extension agencies and farmers participate in individual research activities Farmer participatory approaches are accepted by collaborating institutions Institutional capacity within target institutions allows the activities to take place according to time schedules Resources made available to the project before March 1997

ACTIVITIES	INPUTS		
Stage I 1.1 Information review. 1.2 Participatory rural appraisals in Cochabamba Dept. 1.3 Characterisation of agro-ecological zones. *Stage II* 2.1 Selection of vegetative species based on: survivability; adaptability; suitability for barriers; biomass production; economic benefits. 2.2 Field evaluation of alternative live barrier and cover crop spp. 3.1 Simulation of the effects of live-barriers 3.2 Verification of the model using data 3.3 Development of management guidelines on spacing, widths and plant densities 4.1 Identification of farmer collaborators 4.2 Establish resource availability and requirements for SWC technologies 4.3 Collect economic data on inputs and outputs 4.4 Partial budget and cost-benefit analysis of new technologies 5.1 Farmers and NGOs involved throughout the research process 5.2 Annual project workshops 5.3 Production of extension material 5.4 Manual on research procedures and management of SWC technologies prepared	Inputs and resources being used as planned TOTAL £311 007	Research reports, scientific papers Project reports, Diagnostic survey results Project reports, students thesis, scientific papers Socio-economic data, scientific papers Workshop proceedings, scientific papers, extension material	Continuity of collaborating research staff is stable NGO and farmer participation in research trials Security situation in rural areas remains stable Climatic conditions are not extreme during the research period.

Annex III: Closing inventory of the project (R6621 Bolivia)

INVENTORY AST AT December 1999

Item	Make & Model	Serial No*	Date Rec'd	Purchase Price	Location	Disposal		
						To	Date	Authorised
			University of San Simon, Cochabamba					
1 tonne pick up	Mitsubishi 4X4 double cab	DJNK 320TPOO538	1996	£12 388	UMSS, Cochabamba Bolivia			
Desk top computer	Epson Action 5600	7RM1010026	1996	£2 500	UMSS			
Printer	Epson	2JR1018273	1996	£330	UMSS			
Desk top computer Printer								
			CIAT, Santa Cruz					
1 tonne pick up	Mitsubishi 4X4 single cab	K32TUN5L	1996	£10 500	CIAT, Santa Cruz			
Desk top computer	PC 8600 TW AND SVGA 14"		1966	£2 500				
Printer	Epson Stylus 500		1966	£330				