**CROP PROTECTION PROGRAMME**

# Strategies for forage production and erosion control as a complement to hillside weed management

**R 7579 (ZA 0385)**

# FINAL TECHNICAL REPORT

**Start date: 1 May 2000 - End date: 30 April 2001**

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Project Leader's Institution: Silsoe Research Institute

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# Strategies for forage production and erosion control as a complement to hillside weed management

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## Abbreviations

| | |
|---|---|
| ALB | Associated Live Barrier |
| CIF | Forage Research Centre, Cochabamba, Bolivia |
| CPP | Crop Protection Programme |
| DFID | Department for International Development |
| DM | Dry matter |
| GIS | Geographic Information Systems |
| GM | Green matter |
| Masl | Metres above sea level |
| PRA | Participatory Rapid appraisal |
| PROFOCE | Proyecto de Producción de Forraje y Control de Erosión |
| PROINPA | Promoción e Investigación de Productos Andinos |
| PROMETA | Proyecto de Mejoramiento de Tracción Animal |
| PROMMASEL | Proyecto de Manejo Sostenible de Malezas en Laderas |
| RNRKS | Renewable Natural Resources Knowledge Strategy |
| SEFO | Forage Seed Company, Cochabamba, Bolivia |

**Strategies for forage production and erosion control as a complement to hillside weed management**

**Final Technical Report**

## Executive Summary

The scope of the Project was to develop soil and water conservation practices that produce forage for the livestock of hillside small holders. Building on the outputs of a previous project (R6621), live barriers of grasses and legumes have been established at nine on-farm sites. The sites are all in the Bolivian mid-Andean valley region that is characterized by being high (up to 4000 masl); dry (usually less then 500 mm of rain per year) and cool (average temperatures around 8ºC). Technical and socio-economic evaluations of the barriers have been undertaken to quantify: forage production as a complement to the weed harvest; the nutritive value of the mixtures; the impact on the reduction of erosion caused by weed management practices; and farm families' evaluation of the practices. Phalaris grass (*Phalaris tuberoarundinacea*) has proved to be a remarkably adaptable species, and was used in this Project in association with four legumes to establish associated live barriers (ALBs). These are planted on, or near to, the contour and consist of parallel rows of phalaris separated by about 40 cm. The legume treatments are sown between the rows. Of the four legumes used (*Vicia villosa* [hairy vetch]; *Vicia villosa* ssp *dasycarpa* [woolly pod vetch]; *Trifolium repens* [white clover]; and *Trifolium pratense* [red clover]), the woolly pod vetch gave the best performance. Woolly pod vetch achieved 70-90% emergence, easily outstripping the other treatments; its growth rate was faster, similar to that of the phalaris grass so that the legume was not shaded out; and was able to out-compete the weeds. Woolly pod vetch achieved 40% of the ALB biomass in two of the three collaborating communities. The mixtures with woolly pod vetch also produced the highest crude protein figures of all the ALB mixtures (exceeding 18%). In the short duration of the Project (one growing season) the effects of ALBs on erosion control were always going to be preliminary. However the results were clear and positive, with all barriers accumulating sediment on their uphill side, an effect readily observed by the farmer collaborators. Economic analysis showed that ALBs are a viable proposition, giving positive Net Present Values and healthy cost / benefit ratios. Farmer evaluation pointed to the positive aspects of high green forage production throughout the year, and good erosion control potential. Negative aspects mentioned included the cost of establishment and the "loss" of land that could be used for cash crops. The woolly pod vetch option was a clear favourite in all the farm families' evaluations at all sites. At the final Stakeholder Workshop a follow-up project was proposed which will look at further technical evaluation of associated live barrier species for contrasting agro-ecological conditions, dissemination of results and scaling up the dissemination effort to a higher, landscape, level which will involve another set of decision-making stakeholders. The potential of associated live barriers in the fight against poverty and their contribution to sustainable livelihoods is clear and all efforts should be made to promote this product.

**BACKGROUND**

The Project (Forage production and erosion control – PROFOCE ) has built on the outputs of the recently concluded research projects on hillside conservation in Bolivia (R6638, R6621 and R6447). The work of these projects identified a range of vegetative species for soil and water conservation and soil fertility enhancement in farming systems of the inter-Andean valleys, covering a range of altitudes from 1800 to 4000 masl in the Cochabamba and Santa Cruz Departments of Bolivia (Figures 1 and 2).

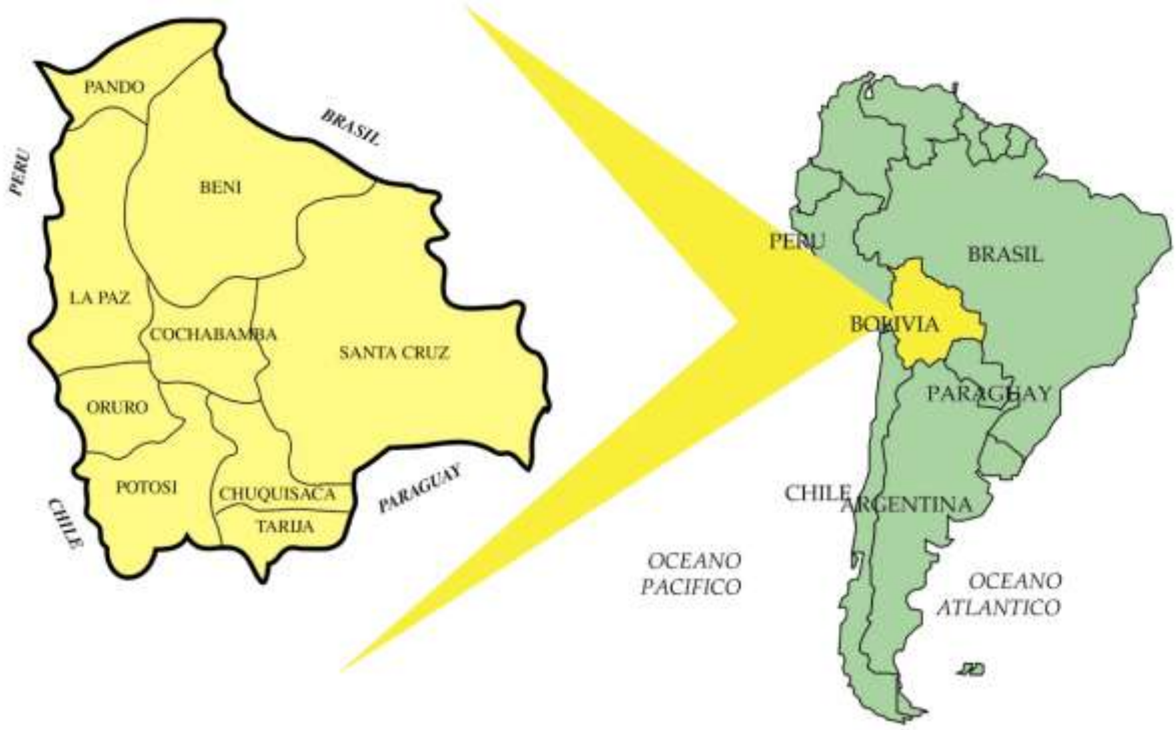


**Figure 1.** Location of Cochabamba and Santa Cruz Departments in Bolivia

**Figure 2.** The high, dry and cool inter-Andean valley region of Bolivia is highly eroded as a result of hillside cultivation and over-grazing.

The outstanding species for live barriers include grasses (especially, *Phalaris tuberoarundinacea, Vetiveria zizanioides* and *Sacharum oficinarum*), and shrubs / trees (especially, *Spartium junceum, Acacia dealbata and Buddleja coriacea*) (Sims, 1997).

A legume selection project in Cochabamba (Wheeler *et al*., 1997) gave indications that soil fertility enhancement can be achieved with N fixing legumes and identified species adapted to contrasting agro-ecological niches (notably: *Vicia sativa, V. villosa; V. villosa* ssp. *dasycarpa, Lupinus mutabilis*) (Rocha, 2000) (Figure 3). Socio-economic analyses show that the use of live barriers can be profitable, especially at the lower altitudes and in more intensive production systems (Ellis-Jones and Mason, 1999).

**Figure 3.** The legume *Lupinus mutabilis* grown as a food crop and green manure on stabilizing hillside terraces.

The hillsides systems projects mentioned have identified soil and water conservation practices compatible with the conditions of the inter-Andean valleys and have demonstrated the potential for adoption of live barriers and leguminous cover crops / green manures. Appropriate species have been identified for a range of agro-ecological environments and have been submitted to technical and socio- economic evaluations in close collaboration with farm families. Target areas have been characterized with Geographic Information Systems (GIS) and Participatory Rapid appraisal (PRA) techniques with the participation of farm families and development institutions (Espinoza and Sims, 1998).

On-farm research plots and farmer experiments have been the catalyst for the diffusion of live barriers. In the area of influence in Cochabamba one specie for live barriers (phalaris grass, *Phalaris tuberoarundinacea*) has been especially successful. The Hillsides Project (R6621) was funded by the Department for International Development (DFID) Renewable Natural Resources Knowledge Strategy (RNRKS) until 1999 when it embarked on a diffusion phase using local sources of finance. To date, some 1000 farm families have benefited from this expansion phase (Sims *et al*., 2000).

**Legumes for cover crops / green manures**

Leguminous cover crops can be used to improve soil fertility in sustainable low-input agricultural systems (Lal *et al.*, 1991 and Kiff *et al.*, 1996). The value of legumes in animal nutrition has been investigated by a working animal diversification project (PROMETA -

R6970) (Rodríguez, 1999; Nina y Velasco, 1999). According to the crop / climate model developed by the Hillsides Project (Keatinge *et al.*, 1998; Wheeler *et al.*, 1997) and field trials, *Vicia villosa* ssp. *dasycarpa*) and *Vicia faba* (amongst other possibilities) are adapted to the conditions at altitudes over 2500 masl.

The valley region of Cochabamba is characterized by annual crops: potato and broad bean, Andean tubers and small cereals. These crops present heavy weed infestation by such species as *Spergula arvensis, Rumex acetocella, Brassica campestris, Pennisetum clandestinum* amongst the most predominant. These weeds are also routinely used for livestock feed as there is a scarcity in the region especially in the dry season. It is, therefore, necessary to consider the possibility of using weeds as forage (Terrazas, 1993). Dimpl (1988) indicates that *Spergula arvensis* can be used as a cover crop in erodible soils and provides fodder rich in protein as well as green manure. On the other hand, many farmers use low levels of production inputs, weed control is generally manual and implies the use of simple tools with human energy for weeding (although occasionally animal traction is also used).

A further DFID funded project, Sustainable Hillside Weed Management (PROMMASEL - R7325) is researching methods of improving weed control to enhance main crop yields. However there is danger that weed control may leave the soil unprotected from the erosive effects of rainfall, and may remove valuable sources of fodder (Webb, 2000). Indeed the draught animal diversification project (R6970) has identified the farm-family concern for the provision of green forage in the long (up to 8 months) dry season, and the frequent need to sell draught animals during this period for lack of available feed. Taking into account these diverse, inter-related, factors the need becomes apparent for combining the production of abundant, high quality forage with the protection of fragile hillside soils against the dangers of erosion.

**Projects**

R6447: Adaptability of cover crops: Bolivia, Honduras, Nepal and Uganda.

R6621: Strategies for improved soil and water conservation practices in hillside production systems in the Andean valleys of Bolivia.

R6638: Participatory improvement of soil and water conservation practices in hillside production systems in the Andean valleys of Bolivia.

R6970: Bolivia: draught animal power project

R7325: Development of integrated weed management strategies for hillsides in the valleys of Cochabamba, Bolivia.

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## PROJECT PURPOSE

The Crop Protection Programme (CPP) purpose of the Project is to promote strategies to reduce the impact of pests and stabilize yields of crops in hillside systems, for the benefit of poor people. In particular, the purpose of PROFOCE was evaluate (in technical, socio-economic and participatory terms) the value, as animal feed and for erosion control, of associated live barriers as a complement to weeds removed through the adoption of new control practices. Annex 1 gives the Logical Framework of the Project.

## RESEARCH ACTIVITIES

*Establishment of research plots*

Research plots were established in areas with contrasting agro-ecological and climatic conditions. We also took advantage of the presence of our sister projects, Hillsides (R6621) and PROMMASEL (R7325), and combined research communities where feasible. Plots were established in three locations Payrumani community in Tiraque Province (Figure 4); Yungataki community (Esteban Arce); Rodeo Alto community (Chapare). Table 1 summarizes the climatic and altitudinal characteristics of the three locations.

**Figure 4** Establishment of associated live barriers with a collaborating farm family in Payrumani

**Table 1.** Characteristics of the Project sites

| Characteristics | Payrumani | Yungataki | Rodeo Alto |
|---|---|---|---|
| Mean annual rainfall, mm | 558 | 592 | 910 |
| Mean annual temperature, °C | 8.4 | 13.5 | 9.0 |
| Altitude, masl | 3350-3650 | 2590-3300 | 3200-3900 |
| Mean annual relative humidity, % | 55 | 45 | 70-90 |
| Ecological zone | Valley head | Valley | Valley |

The selection of species for the establishment of associated live barriers (ALBs)[1] was based on experience gained with smallholder hillside farmers in other projects, and with forage experts in the region[2]. The species selected were:

- Phalaris grass (*Phalaris tuberoarundinacea*)
- Red clover (*Trifolium pratense*)
- White clover (*Trifolium repens*)
- Hairy vetch (*Vicia villosa*)
- Woolly pod vetch (*Vicia villosa* ssp. *dasycarpa*)
- Barley (*Hordeum vulgare*) as a prop for the vetches

The legumes were associated with phalaris grass at the sowing densities indicated in Table 2.

**Table 2.** Associations and legume sowing rates used in live barriers

| Associated live barrier | Sowing rate, kg ha$^{-1}$ |
|---|---|
| Phalaris + white clover | 6 |
| Phalaris + woolly pod vetch + barley | 30 |
| Phalaris + hairy vetch + barley | 30 |
| Phalaris + red clover | 30 |

[1] ALBs are established on hillsides, either following the contour or with a 3% fall if the plot is irrigated, by marking the field with an "A" level at a distance determined by the slope, depth of top soil and the farmers' wishes (Sims *et al*., 1999).

[2] For example, agronomists from the Forage Research Centre (CIF) and the Forage Seed Company (SEFO) in Cochabamba.

| | |
|---|---|
| Phalaris alone as Control | 6-10 slips $m^{-1}$ |

The minimum experimental unit was 5 m of ALB. Although in practice ALBs were always established to protect the entire field offered by the farmer. The phalaris live barriers were established on the contour (or with a 3% slope) with 10-15 cm between slips and in two parallel rows 40 cm apart (Figure 4).

The experimental plots were established in the *mishka* period (irrigated crops sown in June and July 2000) between main crops of potato, broad-bean and oats. In each of the nine plots established, the farmers carried out their normal practices for soil preparation, sowing, cultural operations and harvest. The principal characteristics of the plots are given in Table 3.

**Table 3.** Plot characteristics

| Community | Plot Nº | Slope % | Inter-barrier distance m | Nº of barriers established (and total length m) | Main crop | Irrigation available |
|---|---|---|---|---|---|---|
| | 1 | 20 | 9 | 4 (86) | Broad-bean | Yes |
| Payrumani | 2 | 20 | 15 | 5 (152) | Broad-bean | Yes |
| | 3 | 19 | 14 | 3 (58) | Oats | Yes |
| | 4 | 20 | 11 | 3 (55) | Potato | Yes |
| Yungataki | 5 | 16 | 10 | 3 (185) | Potato | Yes |
| | 6 | 15 | 14 | 3 (52) | Potato | Yes |
| | 7 | 36 | 11 | 3 (44) | Potato | No |
| Rodeo Alto | 8 | 65 | 10 | 3 (35) | Potato | No |
| | 9 | 21 | 15 | 3 (50) | Oats | No |

*Technical evaluation*

The technical evaluation included: establishment; growth rates; biomass production; weed cover; barrier closure rates; nutritive value of the barrier production; and the effectiveness of barriers for erosion control. Farmers evaluated their barriers in their own terms which included their value for forage production and erosion control. The following is an overview of the methods used, full details are given in Vidal (2001).

**In the associated live barriers**

- Percentage emergence and establishment. One month after establishment the number of phalaris plants that had taken root were counted. For legumes the number of emerging seedlings was compared with the seed rates.
- Botanical composition of the ABLs at the time of the first harvest (50% flowering),
- Growth rates. Readings of plant heights were taken on three dates.
- Biomass production. Green and dry matter (DM) measurements were made of the ALBs at 50% flowering of the legumes.

- Bromatological analyses of the DM samples to assess feed values. These were standard tests (ash, ether extract, total protein, crude fibre, N-free extract) and were carried out at the Nutrition Laboratory of the San Simón University.

**In the crop**

- Farmer management of weeds.
- Weed biomass production.
- Weed identification.

**Erosion control**

- Measurements of the depth of top soil were made (with a Hoffer tube) 30 cm above and below the ALBs at establishment and at harvest.

*Socio-economic and participatory evaluation*

The economic evaluation involved registering all the costs and benefits associated with the establishment and maintenance of the ALBs and carrying out an economic analysis (Gittinger, 1982). Clearly in one year it is very difficult for farm families to appreciate the longer term benefits of ALBs, visits to other plots, with barriers already established were a great help in this respect.

Also in this category, the farmers' agricultural production systems were evaluated from the viewpoint of weed management and use. Monitoring the agricultural activities in each crop produced basic information on the importance of weeds as a forage source and the management strategies applied.

Participatory evaluations with farm-families included (Ashby, 1996) both open and absolute evaluations and orders of preference for the different ALB options. Full details are given in Corrales (2001). Participatory evaluations enable us to identify farm-family preferences for certain crop associations from the viewpoint of forage production and erosion control. Additional criteria examined were the availability of seed and the ability of the legumes to compete and produce fodder.

The times most indicated for the participatory evaluations were immediately after the field days in each community.

**Activities References**

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## OUTPUTS

### Technical evaluation

*ALB emergence and establishment*
Phalaris grass is extremely robust are resistant to transplanting stress. Overall there was a 95% success rate in the slips taking root. As far as legume establishment is concerned, Figure 5 shows the percentage emergence after 30 days.

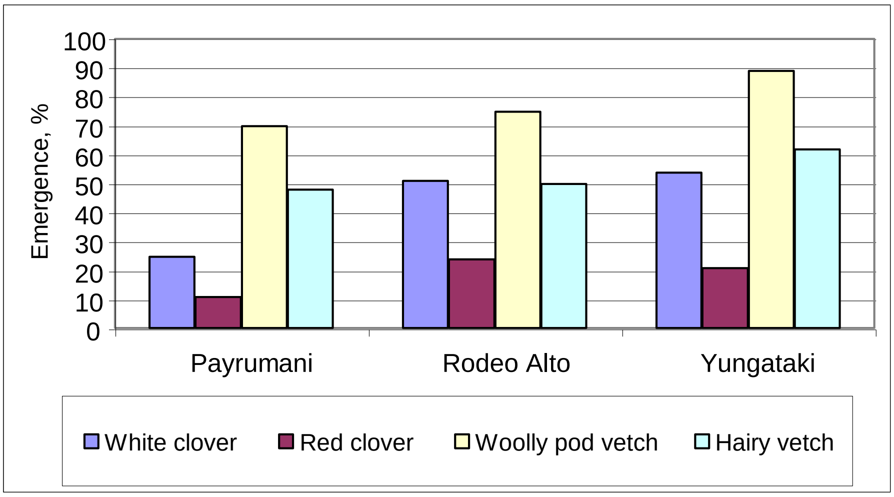


**Figure 5.** Percentage emergence of four legumes in three communities 30 days after sowing

The superior performance in Yungataki (the last community to be included) is due to the farmer innovation of covering the legume seed-bed with grass (*Stipa ichu*) straw to conserve soil moisture (Figure 6). This also avoided the soil crusting encountered in other plots due to the surface irrigation practice. In all cases woolly pod vetch out-performed all other legumes. Emergence figures of under 55% are the result of the inability of the species to overcome the adverse conditions of drought as a result of inefficient irrigation; seed wash with irrigation water and soil crusting. Nevertheless these species have the potential to perform better if sown in the rainy season (not an option in the present short project).

**Figure 6.** A farmer innovation, covering the seed bed with *Stipa ichu* straw, increases the efficiency of irrigation.

*Growth rates*

Growth rates for the barrier species varied somewhat with locality. But in all cases the woolly pod vetch competed well with the phalaris (Figure 7). The clovers tended to be too shaded by the growing grass, until after harvesting when they recovered rapidly (Figure 8). Figure 9 shows the relative performance in growth rates at one site.

**Figure 7.** Woolly pod vetch (*Vicia villosa* ssp *dasycarpa*) competes well with phalaris at all the sites studied.

**Figure 8.** The clovers (*Trifolium* spp.) did not compete very successfully with the phalaris, until the first harvest of the barrier.

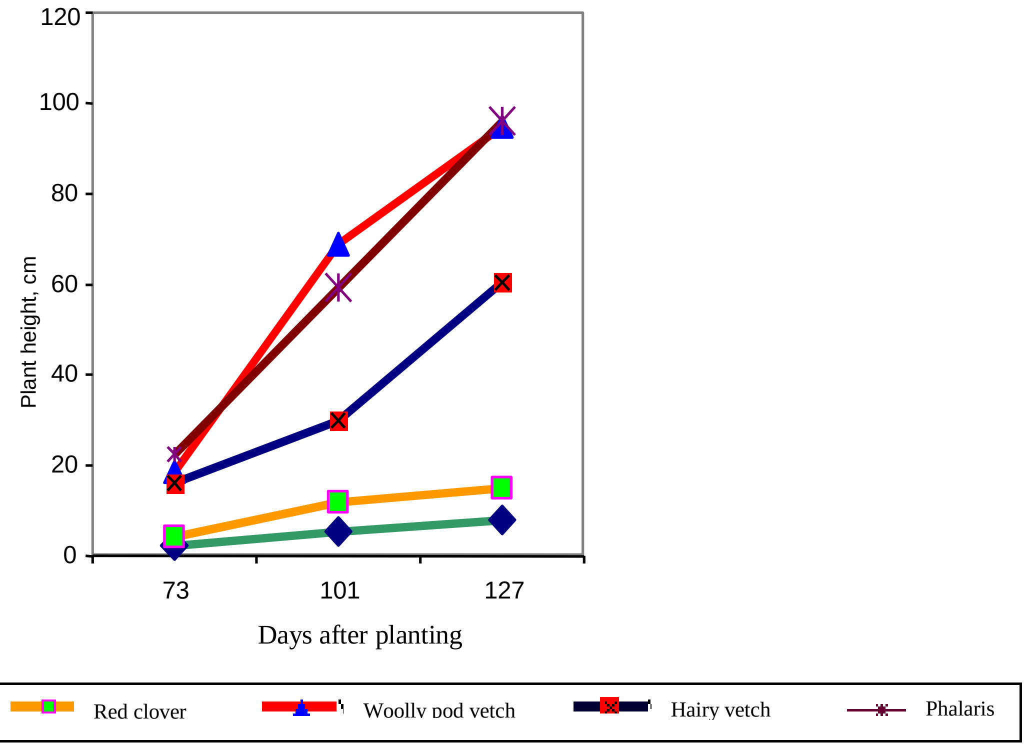


**Figure 9.** Growth rates of four legumes and phalaris. Yungataki.

*Botanical composition at harvest*

As the quality and yield of the forage produced by the ALBs will be influenced by their botanical composition, this was monitored at harvest time. Table 4 summarises the compositions of all the experimental plots.

**Table 4.** Botanical composition of the associated live barriers. Mass of green matter at harvest, %

| Species | Payrumani | | | | | Rodeo Alto | | | | | Yungataki | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **T 1** | **T 2** | **T 3** | **T 4** | **T 5** | **T 1** | **T 2** | **T 3** | **T 4** | **T 5** | **T 1** | **T 2** | **T 3** | **T 4** | **T 5** |
| **White clover** | 6 | - | - | - | - | 10 | - | - | - | - | 8 | - | - | - | - |
| **Red clover** | - | 13 | - | - | - | - | 15 | - | - | - | - | 10 | - | - | - |
| **Woolly pod vetch** | - | - | 41 | - | - | - | - | 20 | - | - | - | - | 42 | - | - |
| **Hairy vetch** | - | - | - | 21 | - | - | - | - | 18 | - | - | - | - | 40 | - |
| **Phalaris** | 72 | 67 | 45 | 66 | 73 | 79 | 75 | 70 | 69 | 75 | 65 | 69 | 45 | 44 | 75 |
| **Weeds** | 22 | 20 | 12 | 12 | 27 | 11 | 10 | 7 | 10 | 25 | 27 | 21 | 10 | 13 | 25 |
| **Barley** | - | - | 3 | 1 | - | - | - | 3 | 3 | - | - | - | 3 | 3 | - |
| **Total (%)** | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

T 1 = Phalaris + white clover + weeds; T2 = Phalaris + red clover + weeds; T3 = Phalaris + hairy vetch + barley + weeds; T4 = Phalaris + woolly pod vetch + barley +weeds; T5 = Phalaris + weeds.

Table 4 shows the consistently good performance of woolly pod vetch, which also competes well with the weed species. It also shows that the clovers have not proved to be well adapted to this type of association under these conditions. Table 5 shows the densities of the four legumes at the three sites. It can be seen that there are inter-site and inter-species differences, both of which merit further investigation at different times of the year.

**Table 5** Densities of legumes at three sites in Cochabamba, plants $m^{-2}$

| | | | |
|---|---|---|---|
| **Location** | Yungataki | 1.599 | a |
| | Rodeo Alto | 1.500 | b |
| | Payrumani | 1.394 | c |
| **Legume treatment** | White clover | 1.860 | b |
| | Red clover | 1.925 | a |
| | Woolly pod vetch | 1.134 | c |
| | Hairy vetch | 1.071 | d |

Means with different letters are significantly different (p=0.05). Duncan's Multiple Range Test.

*Biomass production*

Figure 10 shows the forage production potential of the ALBs in terms of green matter and dry matter. The results from the experimental plots have been converted to kg $ha^{-1}$ by assuming 800 m of 0.7 m wide barrier per hectare (12.5 m between barriers). Giving a barrier area per hectare of 560 $m^2$. Figure 10 shows clearly that the phalaris / woolly pod vetch mixture outperforms the other mixtures at all three communities (p=0.01).

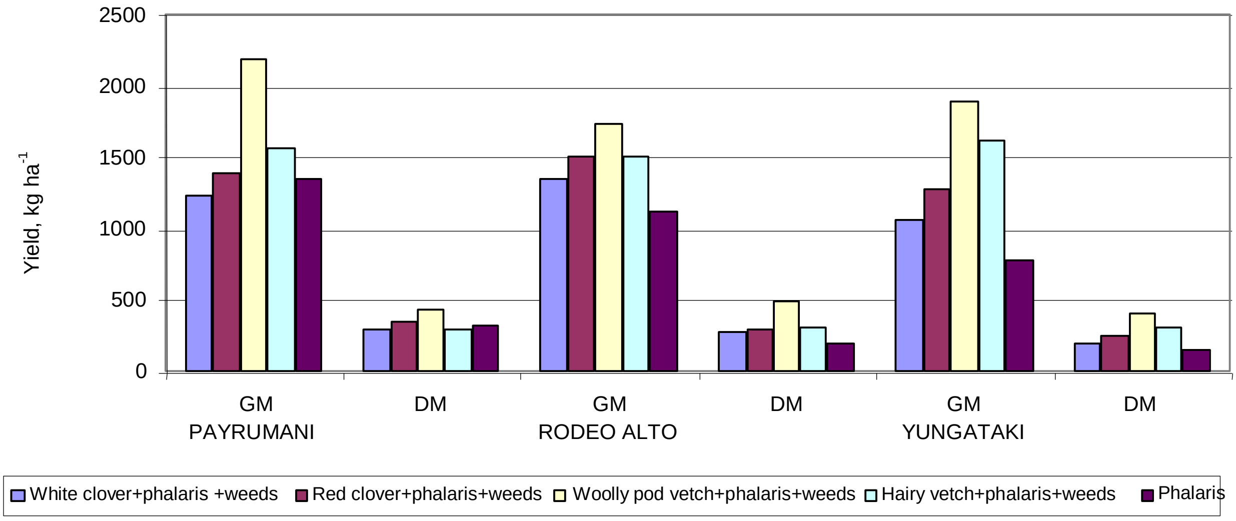


**Figure 10.** Biomass yield of associated live barrier mixtures (expressed as k/ha green matter-GM; and dry matter – DM) at the three sites in Cochabamba

The weeds in the barriers were assessed for species and frequency. For example, the situation in Payrumani is shown in Table 6.

**Table 6.** Mean frequencies of the principal weeds found in the associated live barriers. Payrumani. Plants $m^{-2}$

| **Weeds** | **Phalaris + White clover** | **Phalaris + Red clover** | **Phalaris + Woolly pod vetch** | **Phalaris + Hairy vetch** | **Palaris double row** |
|---|---|---|---|---|---|
| *Spergula arvensis* | 62 | 40 | 33 | 20 | 76 |
| *Brassica campestris* | 2 | 2 | - | 5 | - |
| *Paspalum repens* | 20 | 8 | 2 | - | 28 |
| *Bromus lanatus* | 4 | 2 | 2 | 1 | 18 |
| *Chenopodium album* | 6 | 6 | 4 | | 9 |
| *Lepidium ruderale* | 6 | 2 | 5 | - | 15 |
| *Malva campestris* | 3 | 1 | 2 | - | 5 |
| *Rumex acetocella* | 6 | 2 | - | - | 5 |

It can be seen in Figure 10 that the association of phalaris and woolly pod vetch has the best biomass yields at all sites. Also (Table 4) woolly pod vetch comprises over 40% of the botanical composition in Payrumani and Yunkataki. Furthermore, in Payrumani, it produced seed during the life of the Project due to its short vegetative cycle. As will be seen, farmers expressed a strong preference for using this association for all their live barriers. Table 7 shows the statistical significance of the superiority of this ALB.

**Table 7.** Biomass production (green matter – GM; and dry, matter- DM) of associated live barriers at the three sites. kg $m^{-1}$ of ALB

| **Treatments** | **GM** | | **DM** | |
|---|---|---|---|---|
| Phalaris +White clover + Weeds | 2.183 | d | 0.4611 | c |
| Phalaris + Red clover + Weeds | 2.514 | c | 0.5558 | b |
| Phalaris + Woolly pod vetch + Weeds | 3.474 | a | 0.7928 | a |
| Phalaris + Hairy vetch + Weeds | 2.78 | b | 0.5428 | b |
| Palaris + Weeds | 1.906 | e | 0.4158 | c |

Means with different letters are significantly different (p=0.05). Duncan's Multiple Range Test.

*Forage quality*

In just one year, detailed assessments of the forage value of the different ALB treatments to different classes of farm animals, was not possible. (Although farmers were able to make preliminary assessments that the forage produced was palatable – Figure 11). However the bromatological analysis did show some important differences that point to future research needs. Table 8 shows the botanical composition and the nutritive value of the ALBs in one community.

**Figure 11.** Working animals found the ALB forage palatable. Here a mixture of phalaris and woolly pod vetch is presented to a working ox. Payrumani

**Table 8.** Botanical composition and bromatological analysis of associated live barrier (ALB) forage mixes. Payrumani

| ALB | Botanical Composition (% of green matter) | | DM (%) | Ash | Ether extract | Total protein | Crude fibre | N free extract |
|---|---|---|---|---|---|---|---|---|
| | | | -------------------------------------- -% DM-------------------------------------- | | | | | |
| Phalaris + White clover | W. clover<br>Phalaris<br>Weeds | 6<br>72<br>22 | 26.6 | 8.1 | 1.8 | 10.6 | 23.7 | 47.4 |
| Phalaris + Red clover | R. clover<br>Phalaris<br>Weeds | 13<br>67<br>20 | 27.2 | 8.2 | 2.4 | 12.7 | 22.7 | 45.2 |
| Phalaris + Woolly pod vetch | Dasycarpa vetch<br>Barley<br>Phalaris<br>Weeds | 41<br>3<br>45<br>12 | 21.6 | 9.6 | 2.3 | 18.1 | 22.9 | 38.9 |
| Phalaris + Hairy vetch | Hairy vetch<br>Barley<br>Phalaris<br>Weeds | 21<br>1<br>66<br>12 | 20.9 | 9.6 | 2.3 | 16.9 | 22.9 | 38.9 |
| Phalaris double row | Phalaris<br>Weeds | 73<br>27 | 26.7 | 8.2 | 2.4 | 16.9 | 24.5 | 38.9 |
| *Spergula arvensis* | | | 21.2 | 25.7 | 1.8 | 16.0 | 14.6 | 38.1 |

DM = Dry Matter

Table 8 shows the value of the abundant biomass production of woolly pod vetch in raising the total crude protein content of the mixture. The poor performance of the clovers (6 and 13% of the fresh weight for white and red clover respectively) depresses the nutritional value of the ALB mixture. *Spergula arvensis*, the most abundant weed at this site, is seen to be of good nutritional value. However it is also a host plant for the potato nematode *Naccobus aberrans* that has disastrous effects on the yield of subsequent potato crops.

*Erosion control*

Again, in a short time, the impact of ALBs on soil erosion control can only be suggested. However, as can be seen in Figure 12, the initial observations are extremely encouraging. What is more they are readily observable by farm families and so serve to strengthen their resolve to continue with the ALB practice.

The factors that had most effect in producing erosion and sedimentation, were the soil cultural operations (in the potato crop in Rodeo Alto and Yunkataki communities, these are two earthing-up operations); frequency of irrigation; and the slope (up to 65% in Rodeo Alto). In addition it should be noted that farmers observed the evidence of erosion between the phalaris rows, as well as above the ALBs.

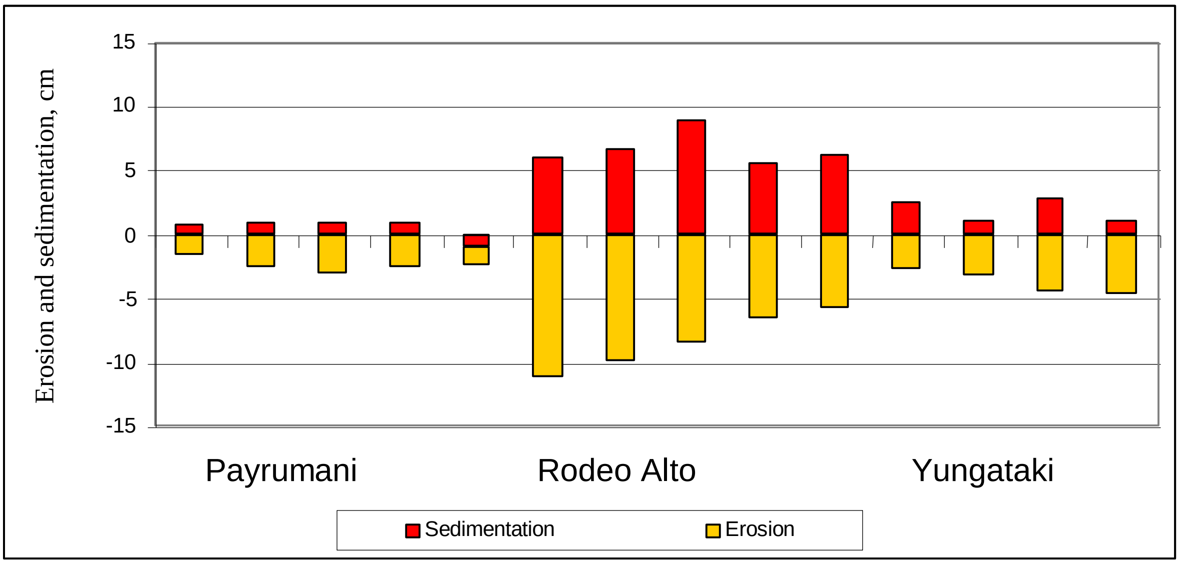


**Figure 12.** Means of soil erosion (-) below and sedimentation (+) above the barriers at the three sites. The bars show the mean figures for each barrier at each site and clearly show the barrier effect that allows soil to accumulate up-slope of the structure

## Socio-economic evaluation

*Economic analysis*

Several basic assumptions were used for the economic analysis[3]:

- For ease of calculation a monoculture of potato is assumed for 15 years.
- The associated live barrier has a useful life of 20 years.
- With conservation, the yields fall by 6% in the first year and then are maintained constant.
- Without conservation yields fall at the rate of 3% per year.
- The opportunity cost of family labour is Bs 20[4] / day.
- There is no market for land in the Project’s communities.
- There is no community organization for conservation works.
- Mean crop yields from the three communities have been used.

Table 9 gives a summary of the economic analysis.

[3] The socio-economic evalaution was done in close association with Jorge Blajos, Economist at the Andean Crops Research Foundation PROINPA

[4] Bs 6.45 = $US1.00

**Table 9.** Summary if the economic analysis for associated live barriers. Discount rate 25%

| **With conservation** | **Community** | **NPV*** | **B:C**** |
|---|---|---|---|
| Phalaris + *Vicia villosa* + Barley (as prop) | Rodeo Alto | 28079 | 2.51 |
| | Payrumani | 57916 | 4.91 |
| | Yungataki | 14908 | 1.81 |
| Phalaris + *Vicia villosa* ssp. *dasycarpa* + Barley (as prop) | Rodeo Alto | 28083 | 2.51 |
| | Payrumani | 57922 | 4.91 |
| | Yungataki | 14908 | 1.81 |
| Phalaris | Rodeo Alto | 28079 | 2.52 |
| | Payrumani | 57996 | 4.94 |
| | Yungataki | 14987 | 1.81 |
| **Without conservation** | Rodeo Alto | 26142 | 2.47 |
| | Payrumani | 58543 | 5.22 |
| | Yungataki | 15384 | 1.87 |

** NPV = Net present Value, in Bs; ** B:C = Benefit : Cost ratio*

Table 9 shows that the potato crop is always profitable. However the B:C situation with no conservation also seems to be attractive by comparison. This apparent anomaly is because there is always an initial investment with the conservation option. Experience indicates that it is also certain that the overall summary hides some important factors, for example that the plot without conservation is unlikely to remain in production for 15 years, the returns after year 10 or so would make it an unattractive proposition and the plot would be abandoned.

*Sensitivity analysis*

An example of a sensitivity analysis applied to the economic analysis is shown in Table 10. The changes made to the original assumptions are:

Scenario (a):

- A reduction of 50% in the price of phalaris slips, assuming that availability improves with increasing uptake.
- A value of phalaris / vetch forage similar to that of alfalfa (Bs 0.70 / kg DM at 19% crude protein)

Scenario (b):

- Zero cost of phalaris assuming that farm families produce their own in family nurseries.
- Value of phalaris Bs 0.40 / kg DM.

**Table 10.** Sensitivity analysis of the conservation of associated live barriers of phalaris + woolly pod vetch + barley, compared with no conservation Discount rate 25%

| With conservation | NPV (Bs) | B:C |
|---|---|---|
| Actual | 28083 | 2.51 |
| Scenario (a)* | 30658 | 2.72 |
| Scenario (b)** | 30450 | 2.79 |
| **Without conservation** | 26142 | 2.47 |

(*a*)* 50% reduction in phalaris slips; value of forage Bs 0.70/kg D M.
(b)** Zero cost of phalaris; value of forage Bs 0.40/kg DM.

The sensitivity analysis, which may reflect the future reality, shows that returns to conservation are always greater than to treatments without associated live barriers.

*Associated live barriers as a complement to the use of weeds for forage*
High value crops (for example potato) are generally kept clean, at least in the early stages of the cycle. This is not necessarily so in other crops where weeds are left to serve as a source of fodder. Analysis shows that it is very worth while (B:C > 3:1) to control weeds in potato, but even so there is a harvest of weed forage at the end of the vegetative cycle. This is an aspect that requires further investigation into farmer practices and the costs and benefits associated with the diverse methods of weed management for animal forage.

*Participatory evaluation of ALBs*
The points noted by farm families in the open evaluation process (free discussion around semi-structured interviews) are given in Table 11. Table 11 shows the different frequencies with which the factors (both positive and negative) were made. It also shows that the most important positive factors are forage production (Figure 13) and soil retention.

**Figure 13.** Participatory evaluations showed that associated live barriers were highly rated as a year-round forage source

**Table 11.** Positive and negative aspects (and their frequency) of ALBs noted by farm families in three communities.

| Payrumani | | | | Rodeo Alto | | | | Yungataki | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Positive aspects | Frequency | Negative aspects | Frequency | Positive aspects | Frequency | Negative aspects | Frequency | Positive aspects | Frequency | Negative aspects | Frequency |
| Produces forage | 4 | Needs soil moisture | 1 | Produces forage | 3 | Needs soil moisture | - | Produces forage | 5 | Needs soil moisture | 1 |
| Retains soil | 3 | High cost | 2 | Retains soil | 3 | High cost | 2 | Retains soil | 4 | High cost | 2 |
| Remains green all year | 1 | | | Remains green all year | 1 | | | Remains green all year | 1 | | |
| High yielding | 1 | | | High yielding | 1 | | | High yielding | 1 | | |

Source: Open evaluation with four farm families in three communities and three treatments analysed.

The absolute evaluation required farm families to express and compare their preferences between the different options on offer. This they did, basing their judgements on their more intimate knowledge of the climatic and soil characteristics of their particular regions. Figure 14 shows their evaluation of the three ALB treatments considered, and in all cases the phalaris / woolly pod vetch combination was the option preferred.

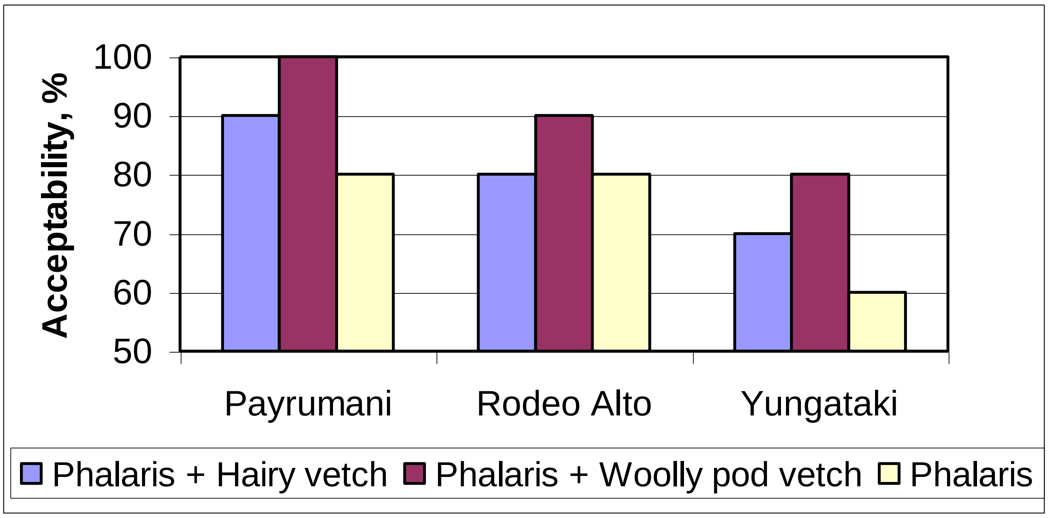


**Figure 14**. Relative acceptance of three associated live barrier options

During the absolute evaluation exercise, the positive aspects mentioned were similar to those found in the open evaluation. Negative aspects included the observation that hairy vetch had a longer vegetative cycle and so was later in producing both seed and biomass; and, of course, the perennial observation that ALBs occupy space that could otherwise be devoted to other crops.

## Publications

The information presented in the preceding Section is a summary of the most important results obtained. A fully detailed account of the complete achievements of the PROFOCE Project will be found in the various publications (including a video) that have been produced during the life of the Project. A Project aim has been to maintain a high profile both in the scientific and farming communities, as a springboard for future activity.

### BSc-level theses

CORRALES, P. (2001). Estudio socio-económico de barreras vivas asociadas. 73 p + Annexes. Universidad Mayor de San Simón, Facultad de Ciencias Agrícolas, Pecuarias, Forestales y Veterinarias "Dr Martín Cárdenas". Cochabamba, Bolivia.
(Socio-economic study of associated live barriers)

VIDAL, N. (2001). Evaluación técnica de las barreras vivas asociadas para el control de erosión y producción de forraje. 50p + Annexes. Universidad Mayor de San Simón, Facultad de Ciencias Agrícolas, Pecuarias, Forestales y Veterinarias "Dr Martín Cárdenas". Cochabamba, Bolivia.
(Technical evaluation of associated live barriers for erosion control and forage production)

### Conference papers

SIMS, B.G. and RODRÍGUEZ, F. (2000a). Estrategias de producción de forraje en compensación al control de malezas. pp. 77-83. In: Proyecto Mejoramiento Tracción Animal, II Seminario taller nacional sobre tracción animal, 9-11 agosto. Universidad Mayor de San Simón, Cochabamba, Bolivia; Department for International Development, UK.
(Strategies for forage production to complement weed extraction)

SIMS, B.G. and RODRÍGUEZ, F. (2000b). PROFOCE. Estrategias para la producción de forraje y el control de erosión como complemento del manejo de malezas en laderas. pp. 67-71. Proyecto de Manejo Sostenible de Malezas en Laderas (PROMMASEL). Memoria primer taller de planificación, Manejo Integrado de Malezas en Laderas, 17-18 agosto. Universidad Mayor de San Simón, Cochabamba, Bolivia; Department for International Development, UK.
(Strategies for forage production and erosion control as a complement to weed extraction)

SIMS, B.G., ROMNEY, D. and RODRÍGUEZ, F. (2000). La importancia de las barreras vivas en los sistemas agropecuarios de los valles. 11p. In: Taller sobre: Optimización de la productividad de sistemas agropecuarios basados en el cultivo de trigo en pequeñas propiedades, 26-28 junio. Cochabamba, Bolivia. International Maize and Wheat Improvement Center (CIMMYT) and International Livestock Research Institute (ILRI).
(The importance of live barriers in agricultural systems in the valleys)

RODRIGUEZ, F. and SIMS, B.G. (2000). Barreras vivas: Un complemento al sistema de siembra directa en laderas. 8 p. In: Seminario Internacional de Siembra Directa Sobre Cobertura Vegetal. 27-29 noviembre. Cochabamba, Bolivia. International Maize and Wheat Improvement Center (CIMMYT).
(Live barriers: a complement to hillside direct seeding)

SIMS, B.G. and RODRÍGUEZ, F. (2001). El proyecto PROFOCE: producción de forraje y conservación de suelo en sistemas de laderas. pp. 1-8. In: Proyecto de Producción de Forraje y Control de Erosión (PROFOCE). Memoria Taller Nacional. Cochabamba, Bolivia. Crop Protection Programme (CPP), Department for International Development (DFID); Universidad Mayor de San Simón, Cochabamba, Bolivia.

(The PROFOCE Project: forage production and erosion control in hillsides production systems)
VIDAL, N. (2001). Evaluación técnica de las barreras vivas asociadas en Payrumani, Tiraque, Cochabamba. pp. 9-16. In: Proyecto de Producción de Forraje y Control de Erosión (PROFOCE). Memoria Taller Nacional. Cochabamba, Bolivia. Crop Protection Programme (CPP), Department for International Development (DFID); Universidad Mayor de San Simón, Cochabamba, Bolivia.
(Technical evaluation of associated live barriers in Payrumani)

CORRALES, P. (2001). Estudio socio-economico de barreras vivas asociadas. pp. 17-26. In: Proyecto de Producción de Forraje y Control de Erosión (PROFOCE). Memoria Taller Nacional. Cochabamba, Bolivia. Crop Protection Program (CPP), Department for International Development (DFID); Universidad Mayor de San Simón, Cochabamba, Bolivia.
(Socio-economic study of associated live-barriers)

CAMPERO, M. (2001). Necesidad de forraje para remplazar cobertura en siembra directa. pp. 27-32. In: Proyecto de Producción de Forraje y Control de Erosión (PROFOCE). Memoria Taller Nacional. Cochabamba, Bolivia. Crop Protection Programme (CPP), Department for International Development (DFID); Universidad Mayor de San Simón, Cochabamba, Bolivia.
(The need for forage to replace cover in direct seeding)

WEBB, M., VILLARROEL, J. and PÉREZ, S. (2001). Manejo mejorado de malezas en sistemas de producción en ;ladera. pp. 33-40. In: Proyecto de Producción de Forraje y Control de Erosión (PROFOCE). Memoria Taller Nacional. Cochabamba, Bolivia. Crop Protection Programme (CPP), Department for International Development (DFID); Universidad Mayor de San Simón, Cochabamba, Bolivia.
(Improved weed control in hillside systems)

COPA, V. and ZABRANA, L. (2001). Especies vegetales no cultivadas como fuente de alimentación de bueyes en Capinota y Tiraque. pp. 41-50. In: Proyecto de Producción de Forraje y Control de Erosión (PROFOCE). Memoria Taller Nacional. Cochabamba, Bolivia. Crop Protection Programme (CPP), Department for International Development (DFID); Universidad Mayor de San Simón, Cochabamba, Bolivia.
(Non-cultivated vegetative species as a source of ox feed in Capinota and Tiraque)

**Edited proceedings**

ESPINOZA, T., RODRÍGUEZ, F. and.SIMS, B.G. (Eds) (2001). La compatibilidad entre el manejo sostenible de malezas y la producción de forraje en sistemas agropecuarios de laderas. Memoria Taller Nacional de Proyecto Producción de Forraje y Control de Erosión (PROFOCE). Crop Protection Programme (CPP), Department for International Development (DFID); Universidad Mayor de San Simón, Cochabamba, Bolivia, 8-9 de febrero. 62 p.
(Compatibility between sustainable weed management an forage production in hillside farming systems)

**Technical bulletins**

RODRÍGUEZ, F. and SIMS, B.G. (2001a). Multiplicación de falaris en viveros familiares. Estrategias para la producción de forraje y control de erosión como complemento del manejo de malezas en laderas (PROFOCE). Department for International Development (DFID); Universidad Mayor de San Simón, Cochabamba, Bolivia. 4p
(Multiplication of phalaris in family nurseries)

RODRÍGUEZ, F. and SIMS, B.G. (2001b). Barreras vivas asociadas. Estrategias para la producción de forraje y control de erosión como complemento del manejo de malezas en laderas (PROFOCE). Department for International Development (DFID); Universidad Mayor de San Simón, Cochabamba, Bolivia. 4p.
(Associated live barriers. Strategies for forage production and erosion control as a complement to weed management)

RODRÍGUEZ, F. and SIMS, B.G. (2001c). Barreras vivas asociadas para la conservación de suelo, agua y producción de forraje. Estrategias para la producción de forraje y control de erosión como complemento del manejo de malezas en laderas (PROFOCE). Department for International Development (DFID); Universidad Mayor de San Simón, Cochabamba, Bolivia. 4p.
(Associated live barriers for soil and water conservation and forage production as a complement to hillside weed management)

**Video**

RODRÍGUEZ, F. and SIMS, B.G. (2001). PROFOCE. Producción de Forraje y Control de Erosión. Barreras vivas asociadas. Una solución para la conservación de suelo y producción de forraje. Video. Spanish and Quechua. 12 minutes. 100 copies. Universidad mayor de San Simón. Cochabamba, Bolivia [Field] (Video).
(PROFOCE. Forage production and erosion control. Associated live barriers. A solution for soil and water conservation and forage production)

**Leaflet**

PROFOCE (Undated). Estrategias para la producción de forraje y control de erosión como complemento del manejo de malezas en laderas. Universidad Mayor de San Simón, Cochabamba, Bolivia. 2p.
(Strategies for forage production and erosion control as a complement to hillside weed management)

**Working documents (Internal to Project)**

RODRÍGUEZ, F. (2000) Curso de capacitación, 25 y 26 de agosto 2000. Conservación de suelos y barreras vivas. Comunidad Rodeo Alto, Candelaria, Chapare, Cochabamba, Bolivia. Final Technical Report. Profoce. 8p [(C)].
(Training course, 25 and 26 August 2000. Soil conservation and live barriers)

SIMS, B.G. (2000). Producción de forraje y el control de erosión (PROFOCE); Mejoramiento de tracción animal (PROMETA); Manejo sostenible de malezas en laderas (PROMMASEL); Alimentación de animales de trabajo (OXFEED); Conservación de suelo y agua en laderas (PROLADE). Cochabamba, Bolivia. Documento de trabajo combinado 4. May – June 2000. Silsoe Research Institute Report IDG/00/14. 29 p.
(Combined Working Document 4)

SIMS, B.G. (2000). Producción de forraje y el control de erosión (PROFOCE); Mejoramiento de tracción animal (PROMETA); Manejo sostenible de malezas en laderas (PROMMASEL); Alimentación de animales de trabajo (OXFEED); Conservación de suelo y agua en laderas (PROLADE. Cochabamba, Bolivia. Documento de trabajo combinado 5. August and September 2000. Silsoe Research Institute Report IDG/00/17. 51 p.
(Combined Working Document 5)

SIMS, B.G. (2000). Producción de forraje y el control de erosión (PROFOCE); Mejoramiento de tracción animal (PROMETA); Manejo sostenible de malezas en laderas (PROMMASEL); Alimentación de animales de trabajo (OXFEED); Conservación de suelo y agua en laderas (PROLADE); Ampliación de rendimientos de investigación (PROAMP). Cochabamba, Bolivia. Documento de trabajo combinado 6. October, November and December 2000. Silsoe Research Institute Report IDG/01/02. 33 p.
(Combined Working Document 6)

SIMS, B.G. (2000). Producción de forraje y el control de erosión (PROFOCE); Mejoramiento de tracción animal (PROMETA); Manejo sostenible de malezas en laderas (PROMMASEL); Alimentación de animales de trabajo (OXFEED); Conservación de suelo y agua en laderas (PROLADE); Ampliación de rendimientos de inmvestigación (PROAMP). Cochabamba, Bolivia. Documento de trabajo combinado 7. January and February 2001. Silsoe Research Institute Report IDG/01/04. 32 p.
(Combined Working Document 7)

**Planned papers for peer-reviewed journals**

A paper is in preparation as a result of an activity closely associated with this Project – the first trials in associated live barriers of tagastaste in collaboration with the Chilean Institute of Agricultural Research (INIA):

RODRÍGUEZ, F., SIMS, B.G. and MENESES, R. (in preparation). El tagasaste (*Chamaecytisus proliferus* ssp. *palmensis*) en Bolivia: experiencias en multiplicación y adaptación del tagasaste en los valles interandinos de Cochabamba, Bolivia.

Peer-reviewed papers on the technical and socio-economic evaluation of associated live barriers are also planned for later in 2001 (authors will include Rodríguez and Sims).

## CONTRIBUTION OF OUTPUTS

Improving hillside farming productivity in the hostile mid-Andean valleys region has a direct effect on rural livelihoods. Decreasing opportunities for off-farm income generation (for example as a result of international efforts to eliminate coca production in the Department) mean that increased, sustainable agricultural production will be the mainstay of regional sustainable livelihoods strategies. Marginal farm families are aware of the precarious nature of their existence. They are also aware of the declining agricultural productivity of their farms, as soil degradation continues unchecked. Hillside soil cultivation and over-grazing are two of the overridingly important factors leading to this situation. The widespread adoption of associated live barriers will not only stabilize hillsides and so halt their productivity decline, but will also provide forage at critical times of the year and so contribute to a reduction in over-grazing.

*What further market studies need to be done?*
The decline in productivity due to land degradation and leading to rural poverty remains an issue of great concern in the mid-Andean valley region. There is a clear and urgent need to promote land husbandry practices that will reverse these processes, and for that there is a necessity to disseminate the results to date and to investigate the most appropriate mechanisms for scaling-up the basket of research results (from this and associated natural resources management projects).

Economic analyses, using values gleaned from farmers' perspectives, are still needed in contrasting conditions in order firmly to ascertain farm families priorities *vis-à-vis* soil degradation. A great deal has been achieved in this field over the last four or five years, but it is clear that more needs to be done.

*How the outputs will be made available to intended users*
The outputs of this Project have already been widely promoted. The Project has run community courses, community-to-community visits and field days. Technical bulletins have been published for both farmers and technicians. Nurseries of phalaris grass have been established, at farm families' request, in the participating communities. A video has been produced which will be used in dissemination activities of other projects, ONGs and development organizations. The relationship that the cluster of DFID –funded projects in Cochabamba has built up over the years means that the present Project's dissemination outputs will be well received and promoted. However, that is not the same as the management of this situation by Project and DFID, for more rapid and widespread impact.

*What further stages will be needed to develop and test the product?*
A further adaptive research project will be required. A relevant Concept Note has been produced as a result of the final Stakeholders' Workshop held by this Project. During this Workshop, a clear need was identified for a more prolonged follow-up activity. The proposed project is entitled: Bolivia: Enhancing the impact of erosion control, weed management and forage production technologies on steep hillsides. The Logical Framework of the proposed project is given in Annex 2.

*How and by whom, will the further stages be carried out and paid for?*
Given DFID's priority of achieving maximum impact from its investment in natural resources management R&D, it is envisaged that the new project will be incorporated into the RNRKS portfolio. To this end the Concept Note has been submitted to CPP management so that it can proceed with funding from CPP and, perhaps, other RNRKS Programmes, such as LPP and NRSP. As a consortium of funding programmes is envisaged, the Concept Note has also been submitted to RNRKS management for information.

**Annex 1.** Strategies for forage production and erosion control as a complement to hillside weed management. Project Logical Framework

| Narrative Summary | Objectively Verifiable Indicators | Means of Verification | Important Assumptions |
|---|---|---|---|
| **Goal** | | | |
| Benefits for poor people generated by application of new knowledge on crop protection to cultivation of herbaceous crops in Hillsides production systems. | To be completed by CPP Programme Manager | To be completed by CPP Programme Manager | To be completed by CPP Programme Manager |
| **Purpose** | | | |
| Promotion of strategies to reduce the impact of pests and stabilise yields of crops in Hillsides systems, for the benefit of poor people. | To be completed by CPP Programme Manager | To be completed by CPP Programme Manager | To be completed by CPP Programme Manager |
| **Outputs** | | | |
| 1. Technical and farmer participatory evaluation of vegetative soil and water conservation measures. | Evaluations done in 3 communities of the role of live barriers as sources of forage and erosion control | Two BSc theses<br><br>Three training workshop proceedings. | Rural communities participate in the research |
| 2. New project proposal for longer term participatory research and development. | Participatory workshop held. | New project memorandum | Research and development institutions continue to collaborate |
| **Activities** | **Inputs** | **Means of Verification** | **Important Assumptions** |
| 1.1. Farmer training workshops for conservation practices. | Total Budget here £53 568<br><br>Three workshops of 2 days delivered in 3 communities | | |
| 1.2. Establishment of on-farm plots of live barriers of phalaris and vicia with collaborating farmers | Minimum of 9 plots established (3 per community). | | |
| 1.3. Nurseries established with farmers. | Minimum of 9 nurseries established (3 per community). | | |
| 1.4. Farmer to farmer visits between communities | At least 3 visits. | | |
| 1.5 Technical, economic and participatory evaluation of development and yield of barriers | | | |
| 1.6. Bromatological analysis of barrier and weed mixtures | | | |
| 1.7. Production of bulletins and videos | | | |
| 2.1. Preparation of a new project proposal based on stakeholders' problems and priorities | | | |

**Annex 2.** Bolivia: Enhancing the impact of erosion control, weed management and forage production technologies on steep hillsides. Project Logical Framework

| Narrative Summary | Objectively Verifiable Indicators | Means of Verification | Important Assumptions |
|---|---|---|---|
| **Goal** | | | |
| **CPP**: Benefits for poor people generated by application of new knowledge on crop protection to cultivation of herbaceous crops in hillsides production systems. | | | |
| **LPP**: Benefits for poor people generated by the application of new knowledge on the improved performance of livestock in forest agriculture interface production systems. | | | |
| NRSP: Improved hillside farming strategies, relevant to the needs of marginal farmers, developed and promoted. | | | |
| **Purpose** | | | |
| **CPP**: Promotion of strategies to reduce the impact of pests and stabilise yields of crops in hillside systems, for the benefit of poor people. | | | |
| **LPP**: Strategies to sustainably improve the production and productivity of livestock of relevance to the resource-poor in forest agriculture communities, developed and validated. | | | |
| **NRSP**: Ways to accelerate and upscale positive pilot research experiences on soil, water and land resource management to the wider community, developed and promoted. | | | |
| **Common purpose** Developing, promoting and upscaling profitable soil management technologies that conserve soil, soil moisture and simultaneously provide improved weed management and high quality fodder for livestock. | | | |
| **Outputs** | | | |
| 1. Improved associated live barrier practices developed and evaluated. | | | |
| 2. Methodologies developed for scaling up the research | | | |
| 3. Promotion and dissemination of research outputs | | | |
| **Activities** | | **Budget: £216 000 (indicative only)** | |

| Narrative Summary | Objectively Verifiable Indicators | Means of Verification | Important Assumptions |
|---|---|---|---|
| **Technical aspects** | | | |
| 1.1. Selection of research areas. | At least five research sites in a range of contrasting agro-ecological regions | | The key assumptions for all activities are: Institutional stability in participating institutions. Availability of suitable, adapted legume species. Key institutions remain enthusiastic about the Project |
| 1.2. Select potential associated live barrier species | In collaboration with CIF, SEFO, Agroleg, select promising legume (minimum 5) and grass species (minimum 2) for the different areas | | |
| 1.3. Establish on-farm experimental plots of species adaptation | Three on-farm plots established in each agro-ecological area | | |
| 1.4. Technical evaluation of the ALBs. | Field and laboratory evaluations and analysis undertaken | | |
| 1.5. Socio-economic and participatory evaluation. | Economic analysis and farm-family appraisal of technology options | | |
| **Scaling up** | | | |
| 2.1. Identification of key actors in the scaling up process | Wide ranging investigation of key decision makers in the scaling up process | | |
| 2.2. Consciousness-raising courses | Course run for key actors to raise the level of knowledge of the practices being promoted | | |
| 2.3. Field visits to on-farm sites | Visits with key stakeholders to on-farm sites | | |
| 2.4. Annual workshops to discuss, disseminate and programme | National workshops held each year (3) | | |
| **Promotion and dissemination** | | | |
| 3.1. Two-weekly radio programme | Radio programmes prepared and being broadcast in all project areas | | |
| 3.2. Dissemination of videos of the technical results | Videos (2) produced and being shown by TV channels in the project areas | | |
| 3.3. Publications for technicians and farmers on ALBs. | Technical (at least 2) and farmer oriented (at least two) bulletins (on ALBs for different regions and nutritional implications of ALBs). | | |
| 3.4. Manuals for practical courses on soil and water conservation and forage production | Instructors' and participants' manuals prepared for technical courses on ALBs and their nutritional value | | |