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GLOBALIZATION AND LOCAL DEVELOPMENT: CHALLENGES TO SMALL SCALE PRODUCTION

# The development of low cost soil and water conservation for smallholder farmers in the mid-Andean valleys of Bolivia.

Brian G Sims, Jim Ellis-Jones and Stephen J Twomlow
International Development Group
Silsoe Research Institute (SRI)
Bedford. MK45 4HS. UK

e.mail: brian.sims@bbsrc.ac.uk
Fax: ++ 44 1525 864014

**SYMPOSIUM TOPIC: Environmental sustainability**

## Abstract

Poverty and land degradation in the mid-Andean valleys of Bolivia are major interrelated problems necessitating approaches that will both improve livelihoods and at the same time lead to improved land use. This paper outlines a participatory research and development process with a number of communities in Cochabamba and Santa Cruz, which has led to increasing use of live barrier and cover crops. These are now being actively promoted by a number of NGOs as well as farmer groups. Research has involved close collaboration between scientists and farmers throughout the process to ensure that farmers' criteria were used in the evaluation process. Successful development of sustainable land use practices at a field scale now need to be followed by consideration of factors that will facilitate upscaling to a landscape or watershed level. This will require close involvement of existing institutional structures taking into account the different interests of all user groups.



Key words: participatory technology development; live-barriers; cover crops; semi-arid; small farmers



## Resumen

Pobreza y la degradación de la tierra en los valles inter-andinos de Bolivia son dos mayores problemas correlacionados, que necesitan un enfoque que tanto mejora los medios de vida, como al mismo tiempo conduce a un uso mejorado de la tierra. Este artículo esboza un proceso de investigación y desarrollo participativo con un número de comunidades en Cochabamba y Santa Cruz, lo cual ha resultado en un uso creciente de barreras vivas y cultivos de cobertura. Estas prácticas se encuentran en el proceso de promoción activa por medio de ONGs y grupos de agricultores. La investigación ha involucrado una colaboración estrecha entre científicos y agricultores durante todo el proceso, para asegurar que los criterios de los agricultores fuesen incluidos en el proceso de evaluación. El desarrollo exitoso de prácticas sostenibles del uso de la tierra al nivel parcelario, ahora debería ser seguido por una consideración de los factores que faciliten su ampliación a nivel de cuenca o paisaje. Esto necesitaría la participación estrecha de las estructuras institucionales existentes, tomando en cuenta los diversos intereses de todos los grupos de usuarios.



Palabras claves: desarrollo participativo de tecnología; barreras vivas; cultivos de cobertura; semi-árido; laderas; pequeños productores

## INTRODUCTION

The livelihoods of smallholder farmers in many developing countries are becoming increasingly precarious with widespread solutions for improving productivity often unavailable. The problems are exacerbated by pressures of demographic growth and declining productivity leading to exploitation of increasingly fragile areas such as hillsides and semi-arid environments. This can lead to environmental degradation. Forest destruction with unsuitable and unprotected land use reduces the capacity of poor people to withstand natural disasters such as hurricane Mitch in Central America and the flooding crisis in Mozambique.

In Bolivia, for instance, the process of desertification has resulted from degradation of land in the arid, semi-arid and sub-humid zones as a consequence of both climatic changes and human activities. It affects over 40% of the land area (450 000 $km^2$) (Franche, 1995; MDSMA, 1996) and it has been estimated that 77% of the rural population is affected and that 60% of these are living in absolute poverty (World Bank, 1996). The Departments most affected are Oruro, Chuquisaca, Tarija, La Paz, Cochabamba y Santa Cruz and include five physiographical zones: the western and eastern cordilleras; altiplano; inter-Andean valleys and the Chuquisaca plains.

Many farmers recognize that one of the specific causes of desertification is the use of traditional tillage practices on steep hillsides (with the ard plow introduced at the time of the Spanish conquest), combined with the lack of adequate conservation and poor hillside irrigation practices. Their response to falling productivity has been to develop a range of conservation practices which include *pircas* (stone walls), *linderos* (boundary hedges), contour furrows and cut-off drains. All of these are low cost farmer-developed systems and form the starting point for the participatory research described.

This paper discusses the approaches that were adopted in a participatory technology development project for hillside soil and water conservation. Some indicative results are presented leading to conclusions on the implications for future work.

## APPROACHES AND METHODS

Work was centered on the valleys of Cochabamba and Santa Cruz, which are highly heterogeneous areas of Sub-Andean Mountains, ranging from semi-arid valleys to areas of cool cloud forest. They are densely populated in places and characterized by out-migration (both temporary and permanent) and soil degradation. At first sight, there is insufficient apparent effort being made by either farmers or development agencies to improve soil and water conservation.

The Soil and Water Conservation project (Prolade) in the mid-Andean valleys is based in the San Simón University in Cochabamba and is the only institution of its kind in the country[1]. Prolade (which initiated its activities in 1996) works with households in the Departments of Cochabamba and Santa Cruz. Initial work project comprised two principal components: the establishment in farming communities of vegetative soil and water conservation practices which have been farmer-

[1]Prolade is a project funded by the Department for International Development of the UK Government.

proven in other Latin American countries; and a process of participatory technology development with farm families in the areas of influence of each research nucleus.

Typical watersheds in the area 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 (Espinoza, 1998; Coker 1998). (Table 1).

**Table 1.** Climatic characteristics of project sites

| PROVINCE | COMMUNITY | AGRO ECOLOGICAL ZONE | ALTITUDE masl | MEAN ANNUAL TEMPERATURE °C | ANNUAL MEAN RAINFALL Mm |
|---|---|---|---|---|---|
| Tiraque | Pairumani (alto y bajo) | | | 8 | 558 |
| | Cebada Jich'ana | Transition | 3400 - 3700 | 9 to 11 | 531 |
| Esteban Arce | Yungataki | Closed valley | 3300 - 3800 | 14 | 592 |
| Cercado | Tirani | Valley head, Puna | 2900 - 4500 | 6 to 14 | 585 – 800 |
| | UMSS | Valley | 2560 | 17 | 528 |
| Vallegrande | Chacopata | Closed valley | 2500-2850 | 12 to 15 | 550-700 |
| Caballero | Los Pinos | Transition | 2600 | 10 to 12 | 55-700 |
| Florida | Pozuelos | Low valley | 1900 | 20 | 850 |

**Participatory research approaches**

Following a number of PRAs in each area (Céspedes *et al.*, 1997a, 1997b and 1997c, Lawrence *et al.*, 1997a) during which soil erosion and declining productivity were identified as priority problems, the research followed a process, including,

- Nov 96 — On-farm researcher managed trials initiated with live-barriers.
- Nov 97 to Nov 98 — Farmers encouraged to experiment with live-barriers.
- Aug to-Sept 98 — Workshops held in each community.
- Dec 98 to Feb 99 — On-farm researcher managed trials with cover crops established.
- Dec 98 to Feb 99 — Farmers experiment with live-barriers and cover crops.
- May 99 — Individual farmer discussions and farmer evaluation workshops.

Different forms of participation were used in different areas. In Santa Cruz this was initially contractual (Biggs, 1989) in which farmers provide land and labour and the design of the experiments, data recording and analysis, whilst discussed with farmers were directed by scientists. In Cochabamba, the style was more consultative with farmers giving their land and labour and being involved in the design and management of the experiments. From the first year a program of consultation with farmers in the three valley provinces of Santa Cruz was initiated (Lawrence *et al.*, 1997b). Through interviews and rural workshops, information was sought on the farmers' priorities with respect to falling productivity. A number of practices were encountered that farmers were already using, but the greatest impact on them came as a result of their visits to the experimental plots of live-barriers and legumes. As a result of this process of discussion and observation, participation became collegial with farmers undertaking their own experimentation. To complement the process of participatory research, a series of community meetings was organized to spread the research results and to establish live barriers with interested farmers. At the same time diffusion occurred as the communities came to understand the technologies whilst participating in the research process.

**Researcher managed trials**

The experimental design used was split plots with three treatments and two replicates (Sims, *et al.*, 1999a). The use of paired plots facilitates immediate comparisons by farmers and eases the collection of agronomic and economic data (Sims *et al.*, 1999b). The treatments comprised live-barriers, of at least 5 m length, of grasses, shrubs and a control without protection. Each treatment covers an area of 25-90 $m^2$ according to the amount of land available on each farm and the distance between barriers (determined by the farmers). In practice the number of barriers established has depended on the interest of the farmers and plots have been established with ten barriers of a minimum 15 m length. Furthermore, farmers have asked for more barriers of the most promising species to be established once they have appreciated the benefits. These barriers did not form part of the experimental design. The technical parameters measured included: barrier closure; terrace formation, slope change and riser formation; growth rates and biomass production. The species evaluated varied according to the diverse agro-ecological conditions, above all the altitude, which covered a range of 1800 to 4000 masl (Table 2).

Once the barriers had been established and the cultivated hillsides started to become stabilized, the second step was to discuss and evaluate methods for improving the fertility of the impoverished soils. It was agreed with the farming communities that the most valuable approach would be to sow legumes for seed and forage and subsequent incorporation. To this end a series of plots was established at the barriers sites using a randomized block design (Rocha, 2000). The parameters assessed included: soil cover; biomass production; soil fertility changes and effect on subsequent crop yields. The legumes evaluated in the different sites are shown in Table 3.

**Table 2.** Species of grasses, shrubs and trees planted in on-farm trials

| GRASSES | BUSHES / TREES |
|---|---|
| *Bromus cartharticus* Vahl | *Acacia dealbata* |
| *Dactylis glomerata* | *Agave americana* L. |
| *Festuca dolichophylla* Presl | *Atriplex halimus* L. |
| *Eragrostis curvula* (Schrader) Nees | *Baccharis dracunculifolia* |
| *Festuca arundinacea* Scherb | *Baccharis latifolia* (R. et P.) Pers. |
| *Phalaris tuberoarundinacea* | *Buddleja coriacea* Remy |
| *Sacharum oficianarum* | *Dodonea viscosa* (L.) Jacq. |
| *Vetiveria zizanioides* (L) Nash (2n=20) Khus. | *Erythrina falcata* |
| | *Gynoxys oleifolia* Musch. |
| | *Leucaena leucephala* |
| | *Polylepis incana* HBK. |
| | *Prosopis juliflora* |
| | *Schinus molle* L. |
| | *Spartium junceum* L. |

**Table 3**. Legumes evaluated in each Department. 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 | *Vicia sativa*; Hairy vetch (*Vicia villosa*); Broad bean (*Vicia faba*); *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*) |

**Participatory evaluations**

During the whole process, the communities evaluated the technologies under observation. They prioritized the various options and gave views on their relative merits. At the end of three years of research a major participatory technology assessment was undertaken in all the communities. This took the form of farmer workshops where the farmers' criteria were discussed and evaluated and conclusions were reached (Ellis-Jones and Mason, 1999).

The species were selected taking into account criteria identified by farmers, albeit before they had gained experience with the various species, including: soil protection; moisture conservation; forage production; and the least space possible occupied by the barrier. For cover crops the criteria of the farmers were production of consumable grains; forage; soil fertility improvement; soil cover and protection. Preferred species depend on climatic conditions but *tarwi* was preferred for marginal soil conditions; rainfed higher elevations. For lower regions with irrigation, the best were broad bean, hairy vetch, common vetch, *garrotilla,* beans, and peas.

In each community farmers were encouraged to participate with and observe the trial plots and to further experiment with those technologies they considered most suitable to their conditions. A number of participatory evaluations were undertaken after the end of each season to assist in making preparations for the next, and finally to evaluate the results of three years of work.

In Cochabamba, by Year 2 of the project it had become apparent that, throughout the region, *Phalaris* was the preferred live-barrier species due to its rapid growth, ability to control soil erosion and it's fodder potential. In Santa Cruz, due to higher rainfall and lower altitudes, there was a wider variety of species selected for experimentation by farmers. In 1998, Acacia, *Phalaris* and *Eragrostis* (weeping love grass) were the species identified as most suitable by farmers in Chacopata and Los Pinos. In Pozuelos, forage cane (*Pennisetum* spp) and *Leucaena* spp were preferred. Acacia and Leucaena were later rejected as their roots made tillage operations more difficult. They were however still considered suitable for windbreaks. However, in practice, nearly all farmers participating actually used Phalaris, other than in Pozuelos where cameroon grass (*Pennisetum* spp). forage cane and vetiver were used.

In both areas the following criteria were identified by farmers as being important at that time: soil retention; organic matter retention; soil moisture retention; fodder availability; no loss of land; no hindrance of cultivation practices; resistance to drought and frost; protection against wind;

improved crop yields; and better tillering. As a result informal farmer experimentation began to spread in the second year, mostly with *Phalaris* (Table 4). From 1997/98, community meetings and planting sessions enabled an increasing number of interested farmers to become involved with experimenting themselves. Seeing the success of one of the formal trials initially motivated all interested farmers.

**Table 4.** Number of farmers involved live barrier trials in each community in Cochabamba

| *Community* | **Researcher managed trials[1]** *1996/97* | **Farmer experimentation** *97/98* | *98/99* |
|---|---|---|---|
| Yungataki | 2 | 2 | 38 |
| Pajcha | 2 | 0 | 0 |
| Pairumani | 2 | 2 | 11 |
| Cebada Jichana | | 8[2] | 8 |
| Chacopata | 2 | 2 | 5 |
| Los Pinos | 2 | 0 | 4 |
| Pozuelos | 2 | 0 | 4 |
| **Total** | **13** | **14** | **69** |

1 Researcher controlled on-farm trials were initiated in 1996/97 for three years.
2 Trials undertaken by a Farmer Researcher Group

Yungataki had a markedly higher participation level for a number of key reasons (Mason, 1999) including:

- The positive long-term presence of two NGOs (Jesús María and CIPCA), which raised awareness and support for soil and water conservation.
- All members of the community have some land under irrigation.
- A near total dependence on agriculture for their livelihoods.
- Consequences of soil erosion are widely visible.
- The area is well suited for *Phalaris* production.

## RESULTS AND DISCUSSION

### Evaluation of researcher managed trials

#### 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. *Phalaris* grass, previously unknown in the area, has proved to be particularly successful. Barrier formation time is greatly affected by field conditions (slope and soil type) and farming practices. Plots where barriers formed in the shortest time have irrigation and produce two crops per year. Rain-fed plots with one crop per year and steep slopes do not form complete barriers until more than 180 days after establishment.

The results presented for all the experimental plots only consider the grass species. Bushes and trees alone have so far not proved to be as effective in controlling erosion (although the combination of Phalaris grass and broom (*Spartium junceum*) is considered). This is not surprising given the short time (three years) available for research in what is the long term process of soil and water conservation.

<u>Barrier closure</u>: For each species the time from establishment to the complete formation of the barrier was recorded. Grasses clearly 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 with time.

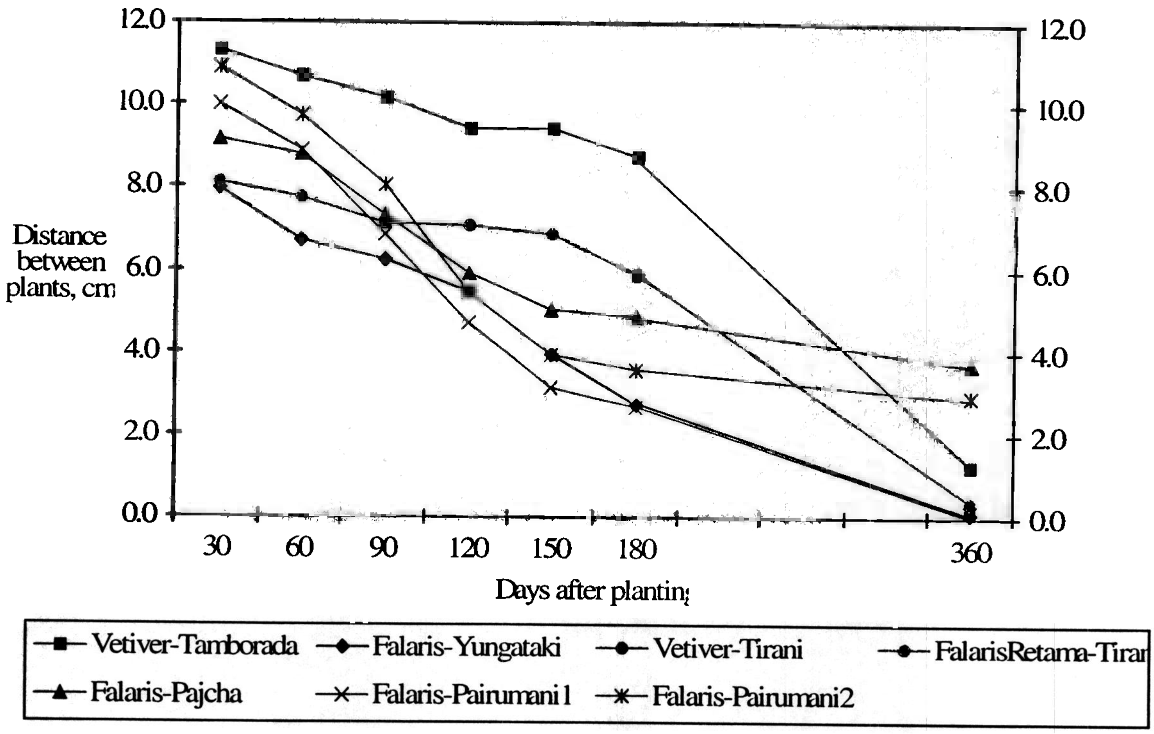


**Figure 1:** Reduction in spacing between grass plants with time

<u>Terrace formation, slope change and riser formation</u>. The changes in micro-topography caused by the barriers have been different for each situation. Table 5 shows changes in inter-barrier slope with time. The greatest differences in slope and riser height are found in plots 2 (Yungataki), 3 (Tirani), and 5 (Pairumani baja) which have the conditions favouring terrace formation already described. On the other hand plots 4 (Pajcha), 6 (Pairumani alta), and 7 (La Tamborada) are rainfed and have abrupt slopes which reduce the tendency to form terraces. Figure 2 shows how the original slope changes and the tendency to form terraces.

**Table 5.** Changes in terrace slope and height of risers due to live barriers

| PLOT | SLOPE , % | | | RISER HEIGHT cm |
|---|---|---|---|---|
| | INITIAL | YEAR 2 | DIFFERENCE | |
| 1 Phalaris | | | | 25 |
| 2 Phalaris | | | 2 | 20 |
| 3 Pha/Broom | | | 3 | 30 |
| 4 Phalaris | | | | 10 |
| 5 Phalaris | | | 2 | 45 |
| 6 Phalaris | | | 0 | 10 |
| 7 Vetiver | | | 0 | 10 |

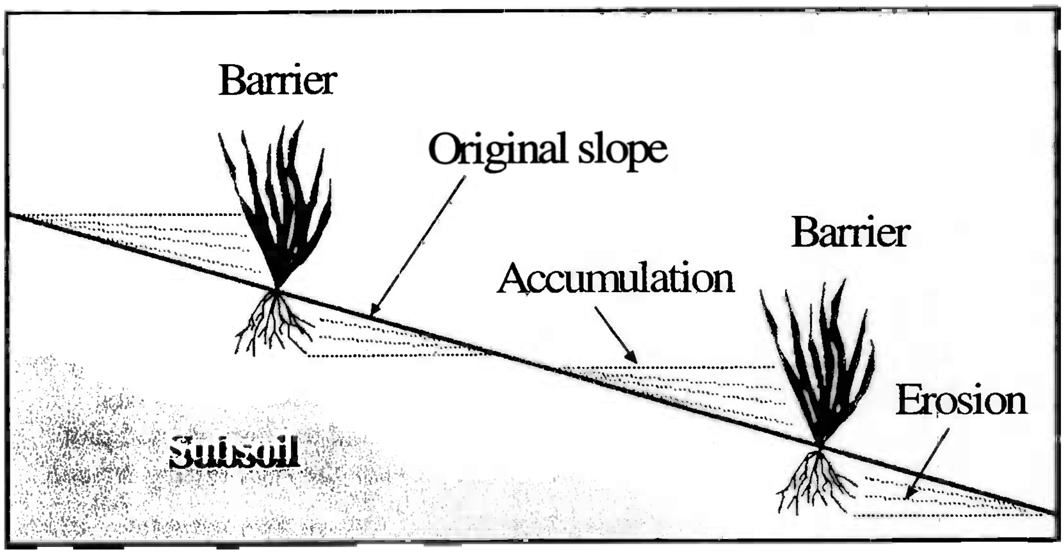


**Figure 2.** Changes in inter-barrier slope and riser formation with live-barriers

The intensity of tillage operations affects the formation of the riser, two crops per year, erodible soil, and medium slopes (15-30%) aid the formation of terraces. Terrace formation is minimal on plots with abrupt slopes (>30%).

<u>Sedimentation and erosion</u>. Installation of barriers has resulted in the deposition of soil above and erosion below. Figure 3 compares the rates in the different experimental sites, 15 cm above and below the barriers.

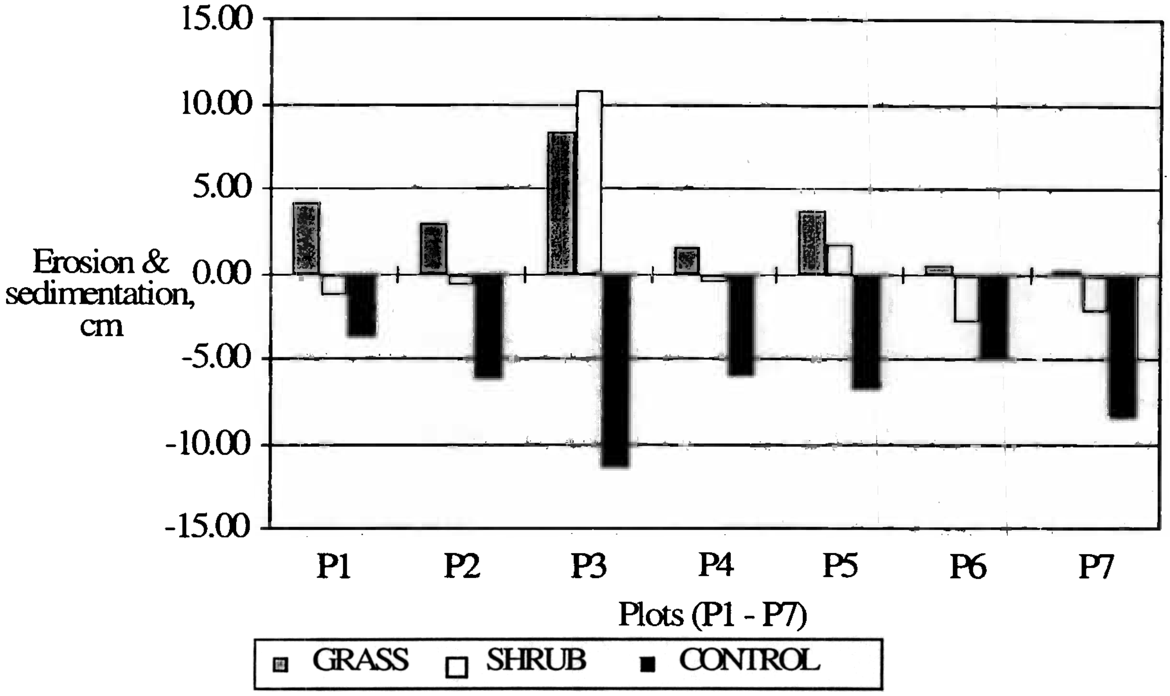


**Figure 3.** Sedimentation and erosion with and without barriers

Maximum values for sedimentation were found on plots 3, 1, and 5 that are caused principally by soil tillage and irrigation. In the case of plot 3, the combination of broom with Phalaris has resulted in greater sedimentation than barriers of grass (vetiver) alone and the unprotected plot shows the greatest soil loss. The stronger root system of broom protects the riser during terrace formation and adds robustness to the system.

Biomass production. Biomass production from the forage species was recorded whilst the plots were in production (Table 6). Fallow plots (which allow communal access to grazing animals) or pastures were not monitored.

**Table 6.** Biomass production of live-barriers, kg $ha^{-1}$ dry matter

| PLOT | YEAR 1 | | YEAR 2 | | TOTAL | | NUMBER OF CUTS | | TOTAL DM |
|---|---|---|---|---|---|---|---|---|---|
| | GRASS | SHRUB | GRASS | SHRUB | GRASS | SHRUB | GRASS | SHRUB | |
| | 1542P | - | 812P | - | 2354P | - | 3 | - | 2354 |
| 2 | 1270P | - | 630P | - | 1900P | - | 3 | - | 1900 |
| 3 | 621 P | 237B | 343P | 88B | 964P | 325B | 3 | 3 | 1540 |
| | 101V | - | 75V | - | 176V | - | 3 | - | |
| 4 | 421P | - | 376P | - | 797P | - | 4 | - | 797 |
| 5 | 239P | - | 1190P | 653B | 1429P | 653B | 3 | 2 | 2082 |
| 6 | 454P | 244A | 189P | 413A | 643P | 657A | 3 | 2 | 1300 |
| 7 | 104V | - | 193V | 743A | 297V | 743A | 2 | 1 | 1040 |

Note : P = Phalaris; V = Vetiver; B = Broom; A = Atriplex

Annual dry matter production is highest in plots 1 and 5, which enjoy better moisture conditions than the others.

**Cover crops / green manures**

The results presented refer to two years of experimentation of four legues in terms of percentage soil cover, biomass production, and potential N incorporation in the soil. The research plots were established in the communities of Pairumani, Tirani, and Cebada Jich'ana, results presented here are from Tirani.

Soil cover. Vegetative cover was assessed at monthly intervals from sowing, with the last measurement being taken just prior to incorporation (Figure 4).

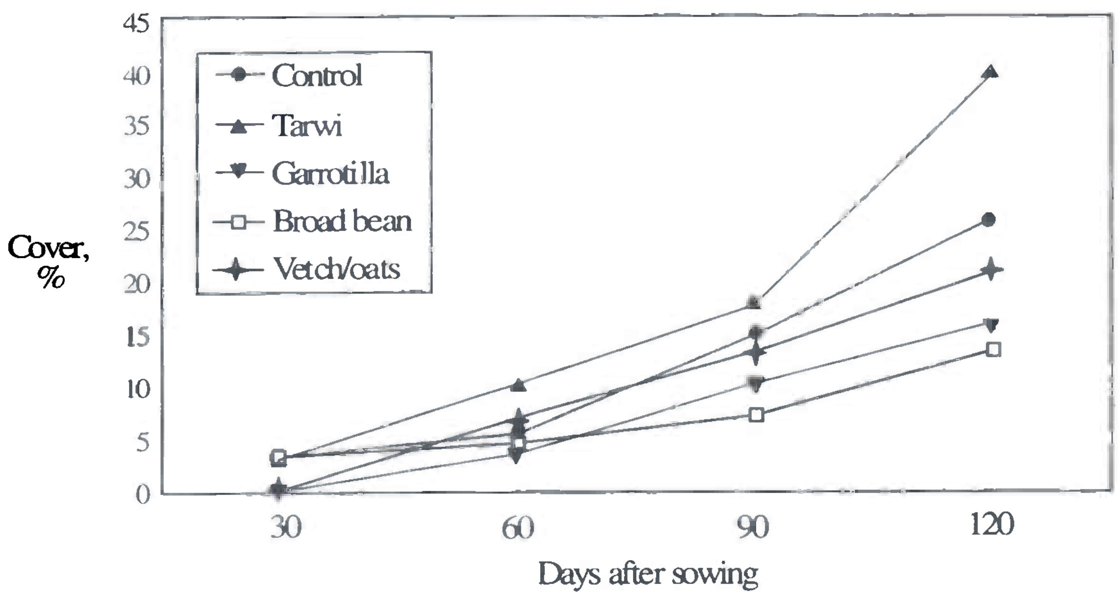


**Figure 4.** Vegetative cover of four legumes

The differences in vegetative cover are highly significant, tarwi was the best option achieving 40% cover. Tarwi was followed by native species (control) and the association vetch / oats with 26 and 21% respectively; followed by broad bean and garrotilla (*Medicago polymorpha*) at under 15%. Water stress significantly affected the development of all species due to the El Niño phenomenon.

Biomass production, N total and C:N ratio. Differences in biomass production were highly significant. Table 7 shows that 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 10 or below which ensures rapid decomposition of the vegetation in the soil.

**Table 7.** Yield of dry matter, total N incorporated and C:N ratio of foliage

| Species | Dry matter | Total N | Total N incorporated | C:N |
|---|---|---|---|---|
| Garrotilla | 227 C | 3.7 | 8 | 2.2 |
| Broad bean | 419 BC | 3.2 | 13 | 3.7 |
| Vetch/Oats | (*)803 B | 2.9 | 45 | 3.5 |
| Tarwi | 2154 A | 7.0 | 152 | 10.0 |
| Control | 380 C | --- | --- | --- |

(*) The dry matter of *Vicia sativa* is 21 % of the total. Numbers with the same letter are not significantly different (p = 0.01) with Duncan's Multiple Range test for dry matter production. Biomass for the Control treatment was not analyzed.

Relationship between soil cover and erosion. Figure 5 shows the poor soil cover (<7%) at 30 days after sowing at the time of maximum precipitation and erodibility of the soil. Hudson (1982) emphasises that intense rains in the spring with recently tilled soil and no soil cover are the most erosive. Hence the high erosion rates at this time are a consequence of this combination of factors added to the steep slopes of the plots.

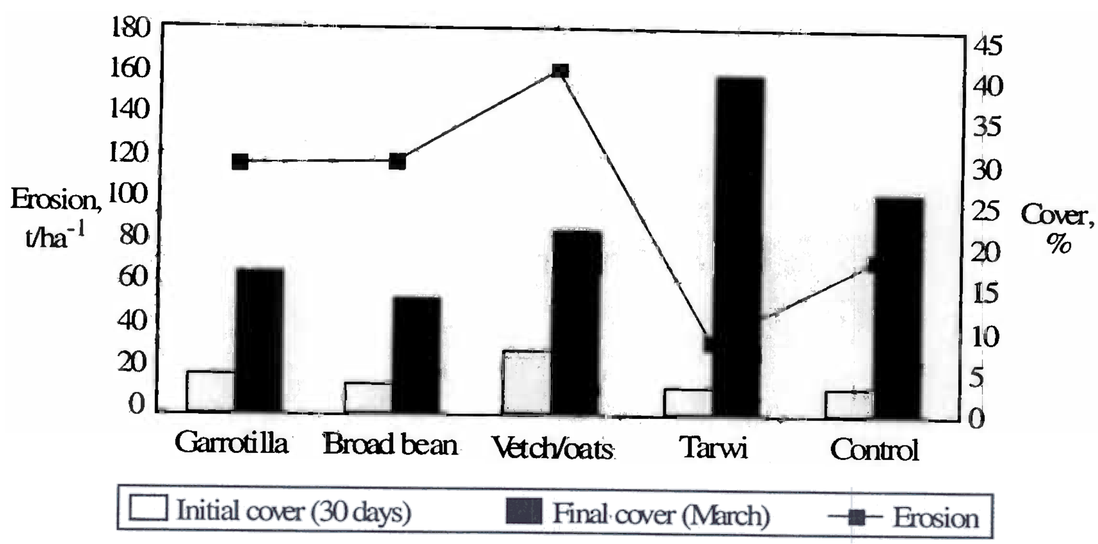


**Figure 5.** Relation between soil cover and erosion

Effect on the subsequent crop. Soil fertility improvements (especially increase in N) as a result of legume incorporation were monitored during the growth period. The effects on yields of a subsequent wheat crop are shown in Table 8 (Rodríguez, 2000a; Rocha, 2000).

**Table 8.** Effect of cover crop incorporation on subsequent wheat yield, kg ha$^{-1}$

| Legume | Community | |
|---|---|---|
| | Tirani | Cebada Jich'ana |
| Garrotilla | 2.1b | 1.6c |
| Broad bean | 2.4a | 3.1a |
| Tarwi | 2.5a | 2.4b |
| Vetch | 1.2c | 1.7c |
| Control | 1.7c | 1.6c |

Means with the same letter are not significantly different (p = 0.05) Duncan's Multiple Range Test.

**Farmer evaluation of conservation technologies**

Consultations after three seasons involved individual and focus group discussions with farmers in each community, as well as discussions with key informants in each area to provide further insight to the problems faced by each community and future priorities for research.

In order to put live-barriers in context, farmers were asked about other soil and water conservation measures currently in use. Although these varied between communities, they can basically be divided into local and introduced practices and may be shorter-term agronomic techniques or longer-term physical measures (Table 9).

**Table 9.** Categorization of soil and water conserving technologies currently used in Cochabamba

| | Long term technologies *(more than one year)* | | Short term technologies *(less than one year)* | |
|---|---|---|---|---|
| | *Indigenous* | *Introduced* | *Indigenous* | *Introduced* |
| Physical or Mechanical measures | *Muros de piedra/pircas* (stone walls)<br>*Linderos* (hedges surrounding plots)<br>*Lark'as* (Diversion canals) | Contour bunds<br>Terraces (often with phalaris)<br>Ditches<br>Stone-walls<br>Gaviones<br>*Bancales* (banks) with fruit trees | *Melgas* (Ridges)<br>*Jallmada* (Tied ridges)<br>*Bordos/calzas* (banks) often on the lower part of field | Reduced tillage |
| Vegetative techniques | *Aynoq'as/Descanso* (fallows) | Live barriers<br>Cover crops<br>Green manures<br>Rotations<br>Afforestation (Wind breaks) | *Shayguas* (lines of other crops)<br>*Cultivos en fajas* (Mixed cropping)<br>*Cultivos asociados* (Mixed cropping) | Mulching<br>Manuring<br>Composting |

Live barriers were compared with other local or introduced technologies. Farmers' criteria for evaluating conservation technologies were identified and matrix ranking was used to compare live-barriers with other technologies. The following criteria were considered desirable for any soil and water conservation technology.

- Need to retain the soil and soil moisture and increases soil fertility and therefore increase crop yields.
- Must be easy to construct.

- Construction/establishment material should be readily available.
- Must allow ease of irrigation.
- Should facilitate working the soil.
- Should not reduce the area for cropping .
- Can be used as field boundaries.

With regard to *Phalaris* the major advantages was that it produces fodder. On the other hand for many areas irrigation is required for maximum efficiency.

It also became apparent that farmers had modified and adapted the use of *Phalaris*, 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. Alternative uses included:

- Growing it as a single species.
- Growing it in mixed species stands.
- Stabilizing irrigation canals and protecting them from run-off debris thus reducing the labour required for cleaning.
- As field borders or *linderos*.
- Planted above stonewalls 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 contour ditches as a slope stabiliser

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 are being planted as soil fertility increases. Particular examples already include onions, tomatoes, and lettuces in Pairumani and flowers in Pajcha. This intensification also requires fencing to control livestock and although it is unclear the extent to which the intensification is related to the barriers as opposed to the fences, clearly both are needed to maximise productivity.
- *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, some fields of *Phalaris* are now being zero grazed. It is fed to all types of stock, (sheep, cattle, equines, and also rabbits). 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 species. They would then use their irrigated fields more intensively
- *Sale of plants* was seen as a possible additional source of income.

**Economic evaluation**

When considering the potential for adoption of soil and water conservation technologies, two sets of perspectives become apparent, that of the researcher and that of the farmers participating in the research. It was often difficult to incorporate fully farmers' evaluation criteria as they were still gaining experience themselves and often found it difficult to identify/quantify or value the factors they consider most important in terms of adoption. Notwithstanding, a clear picture emerged of the key resources and benefits required for adoption of soil and water conservation practices. These farmers identified criteria provided the basis for quantification of the costs and benefits and therefore their economic evaluation (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** |
| *Direct benefits* | *Productivity increase* |
| Increase in crop yields | Increase in yields and their value less any increase or decrease in costs of production. |
| 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 | |
| *Indirect benefits* | |
| Increased livestock fodder | Value of additional fodder, wood, sticks, fruit etc. |
| Firewood and building materials | |
| Fruit | |
| Shade in the fields | |
| **Farmers' perceptions of disadvantages** | **Quantification of costs** |
| Time taken for establishment and maintenance | *Establishment and maintenance* |
| Limited effectiveness in first year | Material (Seed, plants, fertiliser, transport, fencing) |
| Reduction in area for cropping | Labour (skilled and unskilled) |
| Competition with crops for nutrients, soil moisture, and sunlight | *Loss of productivity on lost land* |
| Increases incidence of pests and weeds | Loss of gross margin with no conservation on area occupied by conservation |

**Diffusion of results**

As soon as the success of live contour barriers was agreed by the farm families, Prolade initiated a program of diffusion. The very fact that the research had been participatory and in response to farmer demand meant that adoption was likely to be a relatively easy operation. Prolade's experience has borne that out. From the start the project has worked very closely with local NGOs and development institutions active in its target areas and these are now instrumental in organizing farmers and technician training courses, establishing community and individual level nurseries and collaborating in the production of dissemination literature (Rodríguez, 2000 a and b; Prolade, 1999) and a video.

To date some 200 families have benefited from the adoption of live-barriers (principally of Phalaris grass) and this is set to increase sharply with the agreements signed with three municipalities and a European Union rural development project. Once further on-farm work has been concluded with associated projects, we expect that the incorporation of legumes into the system will enjoy similar success.

## CONCLUSIONS

Prolade, through the establishment and evaluation of live-barriers has demonstrated their effectiveness in protecting hillside soils with different plant species and over a range of agro-ecological conditions. Phalaris grass (*Phalaris tuberarundinacea*) has been the most outstanding success.

The active participation of farmers in the research process has permitted them to observe the effect of barriers on the process of soil erosion and the natural formation of terraces.

The availability of soil moisture is crucial for the establishment of live-barriers and for the subsequent production of forage. Areas with greater moisture contents (those sites with irrigation) and greater agricultural production present the best conditions for barrier adoption.

Tarwi (*Lupinus mutabilis*) is the legume which performs best for the improvement and protection of soil under the widest range of conditions. It produces abundant biomass and resists moisture stress, allowing it to be sown in the dry season and develop well in low-fertility soils where it contributes to improved soil fertility and organic matter content through its incorporated foliage

The degree of soil cultivation and the sowing method have a marked influence on erosion control. The best option is broadcast sowing as opposed to row planting.

The process of participatory technology development has resulted in accelerated adoption, particularly of the live barrier technology. We believe that the fact that farmers were involved in the process from the outset, when they identified their priority for soil and water conservation, has led to almost automatic adoption. The challenge here is to strengthen the dissemination efforts already under way.

Although much of the on-going work is participatory in nature, involving NGOs, farmers and farmer groups, a new approach is now needed. This must scale up field level on-farm trials so that they involve all user groups in a range of agro-ecological niches within a representative number of watersheds. This will require consideration of the existing institutional structures as well as those required to include the different interests of all user groups.

Methodologies must be developed to link individual and group level research with practical community level development. The inter-community implications of watershed management must not be overlooked. Development, within communities, of appropriate skills is a priority, which must be emphasized. 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 and processes for improved community management of watersheds.

Identification and promotion of productivity increasing practices, working with local institutions (identified by the community) for the range of agro-ecological zones within each watershed.

- Development of methodologies for scaling up research results at a field level for community watershed management.

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