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Advances in small-holder participatory soil and water conservation

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Abstract

Increasing demographic pressure and environmental degradation are impairing the ability of small-holder farmers to produce sustainable livelihoods from their farms. This is especially so in marginal areas of the world such as semi-arid and hill-side regions. Although some soil and water conservation (SWC) measures, such as contour ridges and live-barriers, have been widely adopted, uptake has not been great enough to stop or reverse the processes. One of the reasons for this is that the conservation practices on offer do not adequately take into account the farm families' priorities, socio-economic environment, and constraints.

In many developing countries in Latin America and Africa we have found that one of the main goals of small-holder farmers is to maintain or increase the productivity of their land. They often want to achieve this in ways that do not expose them to risky capital expenditure or catastrophic failure in any given year, even though long term averages may be maintained. Farmers' access to information sources is often limited, and the bulk of extension material is aimed at extensionists (where they exist) and not farmers. Women, who often are not part of this process, but who often carry out much field work (especially in Africa) only get information second hand, if at all.

It is clear that that there is no single method of soil and water management that will fit all circumstances. Each technology has its own advantages and disadvantages depending on the agro-ecological conditions (principally climate and soil); crops grown; availability of crop residues; farmer resources and farmers' diverse and complex criteria for decision making. However, acceptable increases in crop yields will only occur when improved conservation practices, (e.g. live barriers and conservation tillage) are combined with improved soil fertility management (e.g. leguminous cover crops / green manures) and effective weed control. Recent research results also indicate that the performance of soil and water management technologies is highly dependent, not only on an extreme variability of the natural potential, but even more on the management capacity of farmers themselves. Unless smallholders themselves develop the understanding and the skills to manage their land in a way which combines production and conservation, the impact of all of this knowledge and research will remain a drop in the ocean.

The R&D program at SRI promotes the use of improved SWC technologies through participatory development and dissemination of appropriate technologies. A partnership between farmers, extension agents and researchers is providing a stimulus

to the process through farmer experimentation and innovation. As part of this process we have been developing guides that address farmers, researchers and extensionists directly, and provide opportunities to all stakeholders to get the information and stimulate discussions among farmers even when there is no formal extension service. Emphasis is being placed on how the farming household can evaluate new ideas and practices through the use of simple paired plot comparisons so that farmers can see whether a new technique is successful, and compare it with their normal practice. Without a comparison it is difficult for the farmer to know whether the new technique is better or worse than the old one. Simple budgets can be developed with farmers that encourage an economic evaluation of a new farming practice and comparison, by the farmers themselves, with the usual practice.

We describe advances in on-farm participatory R&D in SWC in sub-Saharan Africa, and Latin America and discuss their implications for better information flow and adoption.

INTRODUCTION

The results of the demographic explosion in many parts of the developing world have been well documented, but the warning notes do not seem to have been heeded on a scale wide enough to have the long-term impact required. Cultivating marginal areas (especially steep hillsides and Savannahs) leads to accelerated soil erosion and the resulting rapid falls in productivity with declining crop yields and increased incidences of pests, diseases and weeds. Such cultivation is also usually accompanied by forest / woodland clearing and burning, and, whereas the impact of small farmers is tiny compared with the rape of forests knowingly perpetrated by international timber companies in cohorts with corrupt government officials, it still results in large scale destruction of natural resources. Desertification of hitherto productive soils is advancing daily, putting further pressure on land unsuitable for cultivation but needed as an emergency measure to feed hungry families. These forces inexorably result in the poverty which is currently the focus of word-wide concern for its alleviation.

To counteract these erosive tendencies, much R&D effort has been invested in the development of low-cost technologies for soil and water conservation in fragile environments. Research has shown that what are required by farmers are low cost solutions which do not make unreasonable demands on family labor at critical times of the year and which yield returns in the short term. In short, what are required are *adoptable* solutions which answer real problems that have been identified by farm families and, preferably, have been developed with them in a participatory environment.

Although abundant R&D has been done, and technical solutions found, a need has appeared for access to reliable and easily understood information for better application of proven research results. The purpose of this paper is to describe some success stories in Latin America and Sub-Saharan Africa, which have been undertaken by the International Development Group of Silsoe Research Institute during the last few years.

SUCCESSFUL TECHNOLOGIES

Latin America

Since the late 1980s we have been working in Central America (principally Honduras) on the participatory development of low-cost, vegetative soil and water conservation practices for small-holder hillside farmers (Sims and Ellis-Jones, 1996). After extensive consultation and experimentation with local farmers and development institutions it was concluded that contour barriers of grass species offered the best option. Not only do they conserve soil and water, but can also provide valuable fodder for those farmers with a need for this resource.

The value of vetiver grass (*Vetiveria zizanioides*), which has been heavily promoted by the World Bank (Grimshaw and Helfer, 1995), has proved to be an excellent soil conserver when planted on contours established by simple methods such as the A-frame level (LUPE, 1994). The barriers closed through tillering after a year to produce an effective filter for run-off, and the process of terrace formation started almost immediately. Farmers with livestock and a requirement for fresh fodder have preferred barriers of king-grass (*Pennisetum* spp) which, under the Central American conditions of moderate ambiental temperature and rainfall, grows remarkably well. The performance of the grass is similar to that of vetiver, but there are additional management requirements. Vetiver grass does not produce viable seed and so there is no danger of it becoming a potential weed problem. King grass also produces sterile seed but vigorously spreads by means of stolons. If these are not cut back each year (by running a plow along the top and bottom edges of the barrier), then they can invade the cultivated area between the barriers and have a severe yield-reducing effect on the crops grown there.

Once the hillside has been stabilized in this way, then it becomes worthwhile for farmers to increase the fertility of their naturally forming terraces with the use of leguminous species. These can be grown in association with the basic grains crops and then incorporated in the soil to raise organic matter levels and improve fertility. Building on this experience, the hillside project moved on to the more challenging semi-arid regions of the inter-Andean valleys in Bolivia where a three year participatory research project was concluded in 1999.

The Approach

The knowledge that farmers have, concerning their environments and possibilities for agricultural production, is usually far more intimate than that of researchers. On the other hand, well trained and experienced researchers have ready access to technical innovations which could bring benefits to farm families, if they could be shown to be effective. In this spirit we selected eight communities in the Bolivian Departments of Cochabamba and Santa Cruz, which covered a wide range of agro-ecological environments. Community visits and workshops quickly showed that the Andean farmers were suffering catastrophic soil losses with the resulting decline in soil fertility and water-holding capacity. Farmers bemoaned the fact that their hillside plots were becoming unprofitable through falling yields and that they were being forced to migrate to more productive areas in the tropics, or fell Bolivia's remaining forest reserves. They were eager to embark on a program of participatory research to study the value of live barriers and leguminous cover crops and green manures. These concepts were quite new to them and would have been unlikely to have been brought to their notice if the Hillsides Project had not collaborated with them. A further important element in the approach was the Project's close interaction with local NGOs and development projects active in rural development in the region.

The Results

Live barriers

We have tested more than 20 species of grasses and shrubs over a range of 1800 to 4000 masl. Their technical performance, in terms of growth rates, biomass production and erosion reduction, has been monitored. More importantly the participatory evaluation of the species by farm families has revealed the priority that they place on the multi-purpose potential of the barrier material. The outstanding winner on all fronts has been phalaris grass (*Phalaris tuberoarundinacea*). Phalaris will form a closed barrier and an incipient terrace in two seasons. It will remain green throughout the fierce dry season (April to November) when the lack of forage for farm animals is a critical issue, frequently forcing farmers to sell their work oxen. The forage is of high nutritive value, is produced in abundance and stubbornly resists over-grazing.

Leguminous cover-crops / green manures

The work on legumes (over a dozen species) followed the hillside stabilization with live-barriers. The best options are vetches (*Vicia sativa, V. villosa*); tarwi (*Lupinus mutabilis*); garrotilla (*Medicago polymorpha*) and broadbean (*V. faba*). Farmers have found that several management practices give encouraging results in terms of increased crop yield:

- Mixing legumes with annual cereals (maize, wheat and barley) and incorporating them after the cereal harvest.
- Rotating legumes with other crops, and incorporating them directly or after a first picking (in the case of tarwi and broadbean).
- Planting tarwi in degraded soils which are no longer worthwhile to crop.

Animal traction equipment for conservation

In parallel with the participatory work on vegetative conservation measures, a second project, on draft animal management, (Prometa) is investigating equipment for diversifying the use of different classes of work animals (bovines and equines) and developing equipment for hillside conservation. The approach is very similar to that of the Hillsides Project, six communities have been selected which cover the important agro-ecological zones of the inter-Andean valley region of Bolivia (Dijkman *et al.*, 1999). Equipment that has been developed according to priorities set by the participating farm families includes the following which have direct relevance to conservation:

- *Reversible plows.* Prometa has developed two types of reversible plows to facilitate hillside cultivation between live-barriers. The two models have a single central moldboard which rotates through 180° about a horizontal axis. The design adopted for initial batch production has integral shares (Figure 1), whilst the other prototype has a single fixed share. An important aspect of the plow design adopted is that it can be manufactured with different dimensions to be suitable for single equines or single bovines. In this way the farmers' available resources can be more effectively used and their maneuverability improved in comparison with the traditional pair of oxen.

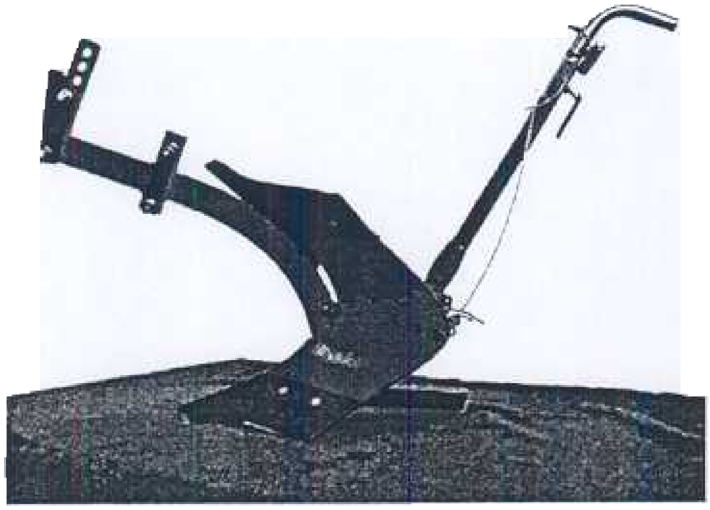

Figure 1. Reversible plow for oxen

- *Winged chisel plow.* Basic tests on the design of chisels for soil bursting in the dry season, and so permit increased infiltration of rain water, have shown that the addition of small wings increase the efficiency of the (Spoor y Godwin, 1978). A prototype winged chisel tine has been evaluated under a range of soil conditions and configurations (Villena, 2000), with the aim of selecting a final version for batch manufacture (Figure 2).

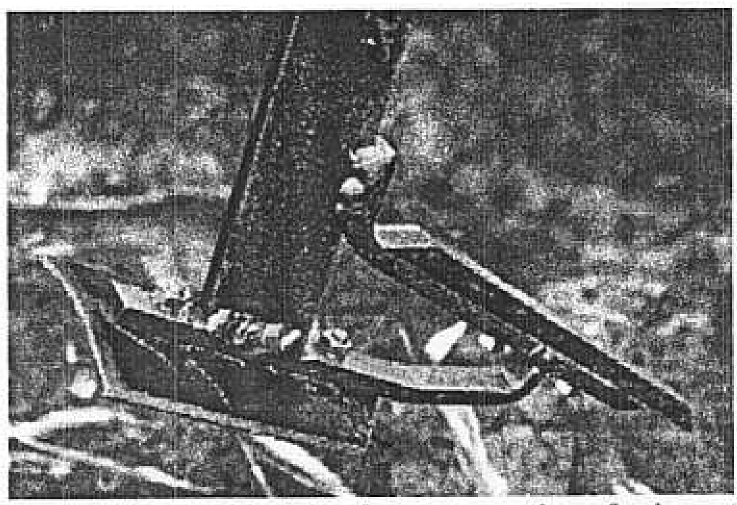

Figure 2. Winged chisel tine for conservation of rain water

- *Improved fallow.* One traditional method of restoring the fertility of hillside soils is to leave plots in fallow (or "resting" in local parlance) for relatively long periods. The *aynoka* system described by Pestalozzi (1997) can include fallow periods of up to 10 years in a 13 year crop rotation. The scarcity of fodder in the dry season is another problem that the farmers have to contend with, to avoid the problem they are frequently obliged to sell their oxen at the end of the cropping cycle. This situation, together with the ample evidence of erosion in the hillsides, resulted in the proposal to improve the quality of the forage produced in the fallow hillside plots. A study of the development of four grass and three legume species in fallow plots has been carried out with participating farmers (Rodríguez, 1999). The results have been very promising as far as forage production is concerned; the impact on soil erosion is being evaluated by the farmers of the collaborating communities.

Direct seeding. The benefits that soil cover imparts to the soil for its protection and improvement, are well known (Wall *et al.*, 1999). In collaboration with CIMMYT, Prometa has developed a series of prototype direct seeders which allow cereals to be sown through straw cover left on the soil surface (Callisaya, 1999) (Figure 3). It should be pointed out that we have not yet arrived at commercial production of the seeder whose main defect is, perhaps, its necessarily high cost. Nevertheless Prometa continues with its development, and with the evaluation of other promising direct seeders from other countries (dos Santos Ribeiro, 2000).

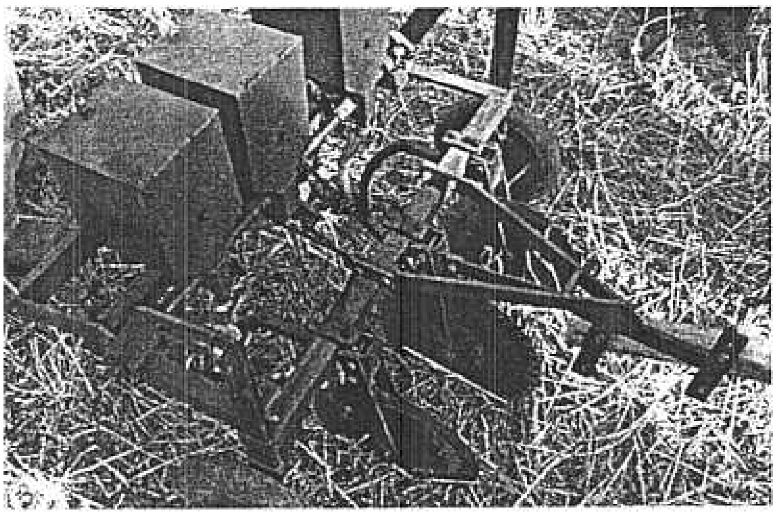

Figure 3. Prototype direct seeder for small cereals

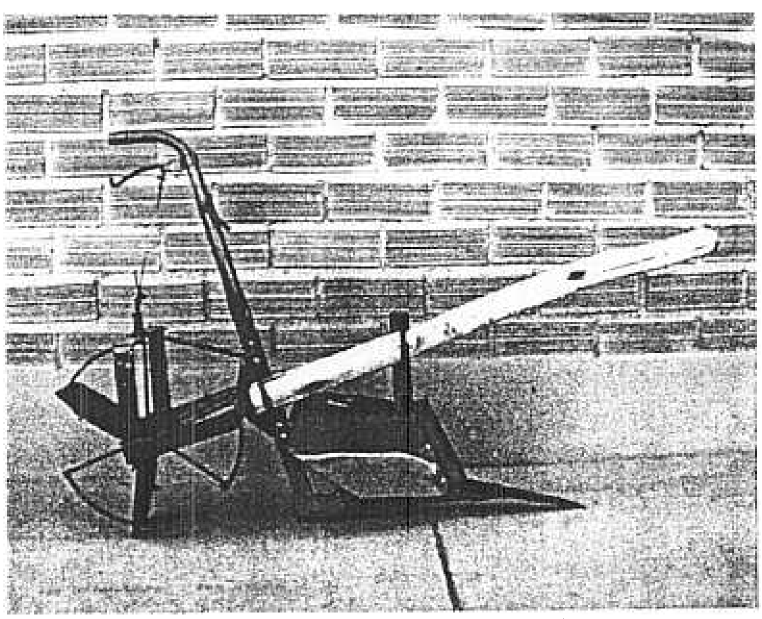

Figure 4. Tied ridger to form ties in furrows for water conservation

- *Tied ridger.* The tied ridger has been developed in conjunction with the wheat improvement project in Bolivia (Protrigo). The design is based on a model developed in Mexico (Méndez *et al.*, 1997). Its rotor (Figure 4) has three blades that rotate when the operator actuates a control cable. In this way small ties can be created along the furrow, so that rainwater can be temporarily stored instead of running off, and can then slowly infiltrate the soil.

Sub-Saharan Africa

In April 1995 a technical workshop on 'Soil and water conservation for smallholder farmers in semi-arid Zimbabwe' (Twomlow *et al.*, 1995) was held in Masvingo to review the state of affairs in the field of soil and water conservation and to formulate recommendations for research and extension. The main outputs of the workshop were that:

- Farmers must be involved in the research process, rather than simply being the object of the research, and;
- The production of a farmer-friendly guide was required to document different soil and water conservation options, indicating the strengths and weaknesses of each, and providing examples of where they have been successful for a variety of climatic and geographical locations in Zimbabwe.

Following on from this workshop, a series of participatory technology development exercises was undertaken to assess crop establishment and weeding options in cotton and maize cropping systems. These included on-station (Table 1) and on-farm assessment (Table 2) of winter, spring and no tillage land preparation options (Twomlow *et al.*, 1999; Twomlow and Dhliwayo, 2000). Planting options were: by hand hoe (Figure 5) ; third furrow plow (Figure 6); open plow furrow (Figure 7) and ripper systems (Figure 8).

Figure 5. Hand hoe planting

Figure 6. Third furrow planting

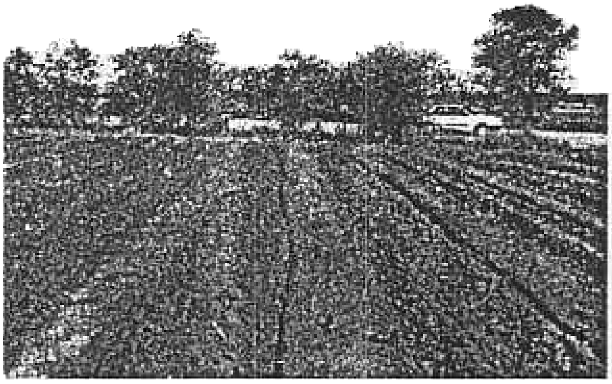

Figure 7. Open plough furrow planting

Figure 8. Ripper planting

Weeding was by hand (Figure 9); plow (Figure 10) and ox-cultivator (Figure 11) combined with creation of tied ridges (post crop establishment) either by plow or cultivator with hilling blades; combining moisture retention and weeding operations.

Figure 9. Hand hoe weeding

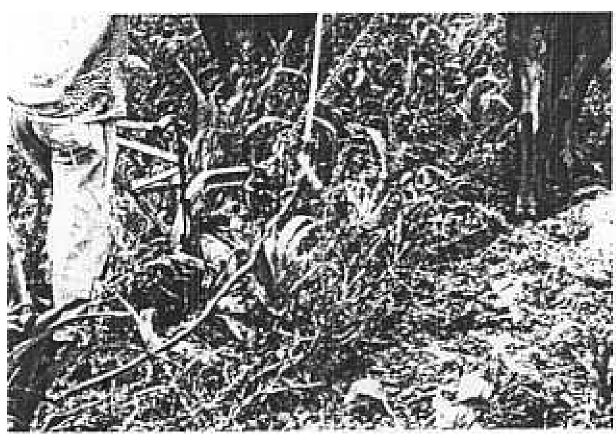

Figure 10. Ox plow weeding

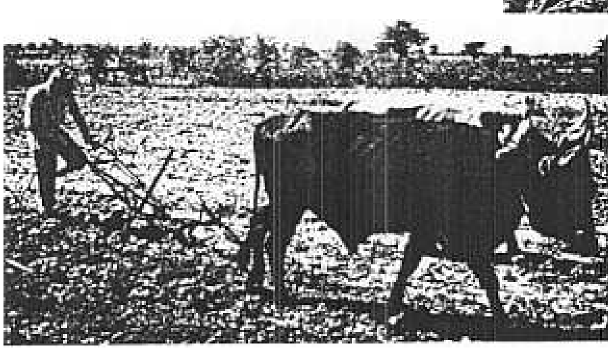

Figure 11. Ox cultivator weeding

Table 1. Maize yield response to methods of crop establishment and weeding on spring-plowed land and winter and spring ploughed land in 1995/96 (Twomlow and Dhliwayo, 2000)

	Spring Plowed Land			Winter and Spring Plowed Land		
Crop Establishment	Grain Yield kg/ha	Total Labor h/ha	Return to Labor kg/h	Grain Yield kg/ha	Total Labor h/ha	Return to Labor kg/h
Hand Plant	620.9	193.1	3.2	596.2	144.8	4.1
Open Plow Furrow Plant	596.8	98.1	6.1	796.3	95.4	8.3
Rip to 0.3 m depth	961.3	105.9	9.1	1276.5	85.9	14.9
Method of Weeding						
Hand-hoe	587.4	194.1	3.0	856.4	166.0	5.2
Ox-Cultivator	953.5	106.2	9.0	680.0	65.9	10.3
Ox-plough	638.0	111.5	5.7	1018.6	88.0	11.6
Tillage s.e.	187.2	6.05***#	2.3*	286.3	7.36***	3.42**
Weeding s.e.	187.2	6.05*	2.3***	247.9	7.24***	2.96*

Significant treatment effect * P > 0.05, ** P > 0.01, ***P > 0.001

On station trials showed similar patterns of yield response for each season, with no interactions being observed between crop establishment and method of weeding. Hand planted plots were significantly weedier and produced significantly (P<0.01) lower maize grain yields than either Open Plow Furrow Plant or Rip planted plots, irrespective of primary land preparation. Weeding practices had no effect on overall grain yield (Table 1). Numbers of barren plants were strongly influenced by land preparation practices, with previously fallowed plots having the highest numbers.

Based on these results, Open Plow Furrow Plant and Rip Plant offer alternative crop establishment options that can be successfully implemented on plowed or fallowed (reduced tillage) land without any yield reduction. In fact, over the four seasons, maize yield increases of between 20 and 300% were observed over hand planting (HP) (Twomlow and Dhliwayo, 2000). In terms of weeding, OPHH performed as well as the OCHH, and when combined with one of the two low-draft crop establishment techniques may provide a viable cropping system for the smallholder farmers with limited draft power.

These crop establisment and weeding combinations were subsequently evaluated in a series of farmer participatory on-farm trials and confirmed that rip planting gave major yield advantages over other crop establishment practices (Table 2). Farmers' perceptions of the crop establishment and weeding options are summarized in Table 3.

Table 2: Summary of results from farmer trials, 1998/99

Crop establishment	HH	TFP	TFP	OPFP	OPFP	Rip	Rip
Cultivation	**HH**	**HH**	**OCHH**	**HH**	**OCHH**	**HH**	**OCHH**
Number of farmer trials	**7**	**5**	**4**	**10**	**9**	**8**	**8**
Yield means (kg per ha)	2209	2040	1634	2732	1874	3394	3072
Margin over purchased inputs (ZW\$)[#]	9088	5036	5445	8987	5515	9158	10101
Margin over purchased inputs, labor and DAP	7887	3827	4235	7618	4174	7951	8887
Labor hours	701	609	450	669	481	707	554
DAP hours	25	30	38	35	43	25	33
Returns to labor (\$ per hour)	13	8	12	13	11	13	18
Returns to DAP (\$ per hour)	315	128	111	218	97	318	269
Rank							
Yield	4	5	7	3	6	1	2
Gross margin excluding labor and DAP	3	7	5	4	6	2	
Gross margin	3	7	5	4	6	2	1
Returns to labor	2	7	5	2	6	2	1
Returns to DAP	2	5	6	4	7	1	3

	Best bet	*Worst bet*
Yield maximization	RIPHH	TFP/OCHH
Unlimited labor and DAP	RIP/OCHH	TFP/HH
Highest gross margin	RIP/OCHH	TFP/HH
Labor limited, DAP unlimited	RIP/OCHH	TFP/HH
DAP limited, labor unlimited	RIP/HH	OPFP/OCHH

Crop establishment methods HH=hand hoe, TFP=Third furrow plow planting, OPFP=Open plow furrow planting, Rip=Rip planting

Weeding methods HH=hand hoe, OCHH=Ox cultivator and hand hoe, OPHH=Ox plow and hand hoe

[#] Zimbabwean \$40 = US\$1

Table 3. Farmers' perceptions of crop establishment and weeding method

Practice	Strengths	Weaknesses
Crop establishment		
Third furrow planting behind plow (TFP)	Combines plowing and planting, giving an overall saving in DAP and labor Ensures early weed control	Poor germination Higher labor and DAP than rip and OPFP
Rip (RIP) or Open Plow Furrow Planting (OPFP)	Good crop emergence DAP and labor reducing Improves soil moisture retention Loosens plow pan Increases yields	Land has to be plowed before planting operation Early weed growth between crop rows Seed may not be well covered
Weeding		
Hand hoe (HH)	Ensures clean weeding	Labor intensive and back breaking
Ox-drawn five tine cultivator (OCHH)	Labor saving and fast for inter-row weeding	Weeds must be small Crop damage
Ox-drawn plow with moldboard (OPHH)	Labor saving, smothers weeds, conserves moisture when ridges tied, promotes drainage in vleis	Crop damage May cause erosion if ridges are not tied

Source: Riches *et al.*, 1998

Through working closely with farmers the following criteria were identified as key to adoption:

1. The need to match technologies to farmers' resources.
2. The availability of draft animal power.
3 The poor performance of farmers' draft animal implements due to poor maintenance and use.
3. Lack of skills amongst local artisans to provide maintenance and repair facilities, or fabrication of simple tie-makers or ripper tines.
4. Lack of access by farmers to reference material on existing or improved technologies, relying totally on local extension workers and other farmers for dissemination.
5. Manufacturers being unwilling / unable to supply new implements without guaranteed sales.
6. Farmers being unwilling / unable to adopt new systems due to lack of innovative implements and back up technical support.

DIFFUSION STRATEGIES

Latin America

Without a doubt the conclusion reached as a result of our experiences has been that community participation in the research and development process is the best route to dissemination and adoption. Participatory research needs technical input from scientists and for this reason we have produced a researchers' guide to research with smallholder hillside farmers (Sims *et al.*, 1999a).

The Project is now in its diffusion stage and, since 1999 has been able to satisfy the demands of over 1000 farm families for training and planting materials (principally of phalaris grass). We have embarked on a program of two-day practical courses in the worst affected communities and have produced farmer guides and a video, based on farmers' comments, to illustrate the principals involved in applying the techniques (Agrecol, 1999; Rodríguez, 1999a; Rodríguez, 1999b).

Sub-Saharan Africa

Extension material

The focus of the proposed extension material was not to promote blue prints, but rather to encourage farmers to try out ideas and modify / adapt the different soil and water conservation options available to their own circumstances. A review of the existing literature available has shown that this is the missing link in communication for successful dissemination within a participatory extension approach. So far, most materials have been geared towards extension staff rather than the farmer.

Methodology

The first stage in the preparation of the guides was to collect all of the published and unpublished extension and research related materials on semi-arid soil and water management in Zimbabwe (Twomlow and Hagmann, 1998). The materials collected were then presented to a number of farmer groups, facilitated by the Zimbabwe Farmers Union, who ranked the materials in terms of usefulness and ease of use (no assistance required from extension staff).

Figure 12. A group of farmers ranking materials currently available in Zimbabwe

Once the rankings were completed, farmers discussed what they liked and disliked about the materials and made suggestions as to how they would like reference material presented (Figure 12).

The key issues raised were that text should be simple and quite large, supported by line drawings. Where a technology was being described, it should be presented as a series of numbered steps that would be easy to follow. Based on the findings of these meetings initial drafts were prepared and comments solicited from extension and development specialists with some limited field testing with farmers. Initial reactions were very positive. A full workshop was held in May 1998 with all interested stakeholders, to agree technical content, format and distribution procedures. The meeting agreed that the guide should be promoted jointly by the Zimbabwe Farmers Union and Agritex. Revisions of the material have been made and a final draft is now with the Zimbabwe Farmers Union for translation into the local vernacular (Figure 13), with English versions currently being used in over 50 communities.

CONCLUSIONS

- Research in small-farm systems in hostile environments has not always, in the past, resulted in satisfactory adoption. Involving farming communities in the R&D process in partnership with scientists can now widen the pathway for adoption through participation to reduce rural poverty.
- Participatory research should focus on simple practices with observable results which produce benefits in the shorter term.
- Soil and water conservation is a farmer priority in hillside and semi-arid environments. Low-cost techniques such as vegetative contour barriers, leguminous cover crops and conservation tillage have been shown to be attractive options for resource-poor farmers.

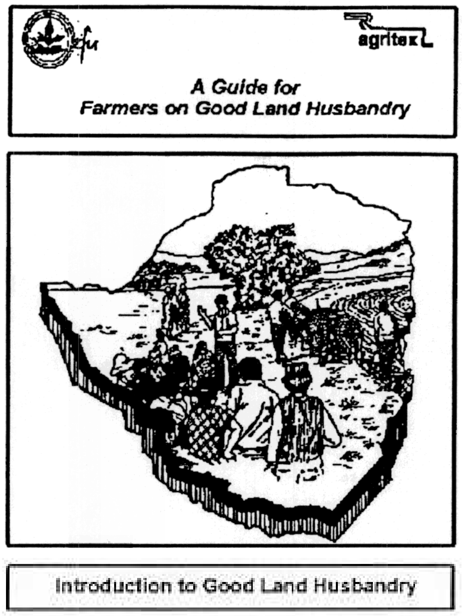

Figure 13. "Farmer approved" extension

- The preparation of user-friendly extension material, approved by both farmers and researchers, is a necessary corollary to the R&D process, and should be used in conjunction with practical on-farm short courses.
- The way forward should be to aim for <u>more</u> participation with farming communities and to advance the idea of farmer experimentation through the formation and support of farmer research committees and farmer field schools which involve <u>farmer</u> experimentation, with technical guidance as requested.

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