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Participatory Land and Water Management: Silsoe Research Institute's Experiences from Latin America and Sub-Saharan Africa

Brian G. Sims, Steve J. Twomlow and Jim Ellis-Jones*

ABSTRACT

Soil conservation has been promoted in many developing countries over the last 50 years and many technologies have been developed. Despite this, the extent of land degradation resulting from water and wind erosion is increasing. Historically, projects have concentrated on the introduction of technologies designed elsewhere, but high failure rates and low adoption indicate that this approach is inappropriate. Consequently the International Development Group at Silsoe Research Institute (SRI) in the UK has, over the past decade, been working with small-scale farmers in Latin America and sub-Saharan Africa to develop participatory methodologies that build upon: 1) Traditional farming methods in Zimbabwe, 2) Indigenous soil and water conservation systems in Kenya and Tanzania, and 3) Leguminous cover crop and live-barrier species for a wide range of agro-ecological and social environments in Bolivia and Honduras.

Our work suggests a more enlightened approach to land stewardship; the principle is that development should be promoted by building on what farmers are already doing. We focus on concerns such as moisture conservation and fertility enhancement for crop production and we are partners with farmers throughout the process of research identification, planning, implementation, monitoring, evaluation and dissemination.

Assessments focus on technical and economic viability, social acceptability and adoption practices of conservation technologies. Evaluations have included their ability to reduce runoff, slow the rate of soil erosion, increase soil moisture availability and enhance soil fertility. The work has broadened the understanding of the technical and economic performance of these technologies, as well as providing greater insight to farmer selection and decision making criteria.

INTRODUCTION

Soil conservation has been strongly promoted in almost every developing country over the last 50 years and a large number of technically sound conservation technologies has been developed and promoted. Despite this, the extent of land degradation resulting from water and wind erosion is greater than ever before. Soil loss worldwide has been valued at US$400 billion per annum, based on the cost of replacing the loss of nutrients and other on and off-site damages (Pimmental, 1995).

Soil erosion has frequently been perceived as the chief cause of land degradation, yet the limited effectiveness and low adoption of widely promoted anti-erosion measures make it necessary to reconsider the causes of, and alternative measures to counter, land degradation. Soil conservation technologies are inherently different from other crop improvement technologies such as fertilizers, pesticides and improved seeds as farmers would expect to see benefits within a cropping season from such investments. However the construction and maintenance of conservation measures may involve significant initial and ongoing investment in both cash and labor with difficult to quantify benefits being realized in the longer term.

Under increasing population pressure rotational bush fallow periods, which often allowed adequate recuperation of soils, are increasingly being shortened. Measures such as conservation bunds, terraces and ditches have been widely introduced to farmers using a top down approach, often under coercion, or with subsidized programs. These measures often had little lasting effect and land productivity has continued to decline.

New measures are required to counter the frequent failure of physical structures. One is the identification and promotion of suitable live-barrier species for contour planting on hillsides, which has had considerable success in higher rainfall environments but less so in drier regions (Sims, 1999). On their own, however, live-barriers are likely to enjoy limited success; they need to be combined with other measures that can improve soil moisture and nutrient availability which include combinations of reduced tillage systems, incorporation of organic matter from cover crops and green manures, the use of crop residues as protective mulches, use of composts and other soil improving practices.

Traditional systems are sustainable under conditions of low population pressure and lack of outside influences when productivity is geared towards subsistence. Under these circumstances production and conservation are adapted to the limits and potential of the natural resource base. Resource management systems focus on regeneration, recycling and conservation. Rapid growth without adequate conservation will degrade the resource base and sustainable intensification requires soil erosion control, moisture conservation and maintenance of soil fertility.

Innovation can be developed indigenously or result from external intervention. Well-documented examples of successful transformation from poverty include the Machakos in Kenya (Tiffen et al., 1994) and community forestry management in various countries (Jackson et al., 1998). The role of markets in

*International Development Group, Silsoe Research Institute, Wrest Park, Silsoe, Bedford, MK45 4HS, UK. Corresponding author: Brian.Sims@bbsrc.ac.uk.

the Kenya example was key to increasing productivity linked to soil conservation. Surveys on the use of indigenous technologies (Critchley et al., 1994; Reij et al., 1996) have concluded that it is desirable to build on existing systems rather than to introduce external technologies, which may not be technically sound or viable.

The purpose of this paper is to present the results of participatory research by SRI aimed at poverty alleviation in marginal agricultural areas through land productivity enhancement achieved by means of soil and water conservation (SWC) and increased soil fertility.

Building on tradition in Sub-Saharan Africa

In a recent farmer participatory study in Kenya, we identified eight locally practiced soil and water conservation technologies common to the semi-arid regions of Embu District that were subsequently evaluated over four cropping seasons under controlled conditions at Machanga Research Station (Okoba et al., 1998). The practices included various sizes of trash lines with different horizontal spacing and various sized stone bunds compared to a flat control and *Fanya juu* (contour ditches with the soil thrown up-hill), the recommended technology for the region. Crop yields; runoff, soil losses and water contents were monitored. Results showed that mobile trash lines (moved 3 m down slope every season) and trash lines with spacing between structures reduced to 7.5 m, consistently reduced runoff and soil loss and increased yields when compared to the control (Table 1). More importantly, soil losses from the permanent structures such as stone bunds and *Fanya juu* at 15 m spacing were consistently greater than the control plots, but this is due to the large amount of soil disturbance during construction. In the southern highlands of Tanzania the *Ngoro* or *Matengo* pit and the *Matuta* ridge systems are two traditional soil and water conservation technologies that have been locally developed in response to prevailing environmental and socioeconomic constraints (ICRA, 1991; Ellis-Jones et al., 1998a). The *Ngoro* system, used mainly on steep slopes, consists of a regular series of pits with crops planted only on the surrounding ridges; under which buried plant residues are decomposing. In the alternative *Matuta* ridge system, all vegetation prior to hand tillage is slashed and the residues roughly aligned across the hillside, as in the *Ngoro* system, with soil thrown down slope to form a ridge over the organic residues. However, if labor is limiting the organic residues are burnt prior to ridge construction. Both systems are said by their respective proponents to conserve moisture in the soil, reduce soil erosion and, where organic residues are incorporated, improve soil fertility (Ellis-Jones et al., 1998a).

From recent studies (Martin et al., 1998a, 1998b) we found that *Ngoros* were generally larger than the historically quoted 1.5 m by 1.5 m. The average size of a pit is 2.4 m long by 2.1 m wide aligned down the slope with only limited evidence of sheet erosion. This is in contrast to fields with the *Matuta* ridge system, where gullying was the dominant form of erosion. In fact erosion only failed to occur on those ridges aligned on the contour or combined with live barriers. In the *Ngoro* system, the majority of soil was redeposited in the pits, meaning a small, if any, net loss of soil, but in the ridge systems much of the soil was transported out of the study areas.

On a seasonal basis no statistical differences were observed in the amount of water stored under *Ngoro* or *Matuta* ridge systems irrespective of slope. Nevertheless, economic analysis has indicated that *Ngoro* provides highest productivity where fertilizer is not applied; though at low soil fertility levels all systems are likely to give reduced gross margins (Table 2). Table 2 also shows that, where fertilizer is applied the *Matuta* ridge systems are likely to give higher returns. Future work in Tanzania should concentrate on the introduction of field boundary management techniques that prevent water runoff from land above entering fields and creating erosion problems; alignment of tillage systems, particularly the ridges along the contour; and introduce some form of physical (preferably biological) barrier that can reduce slope lengths. Lastly, but importantly, farmers need to understand the economic value of fertilizers and organic matter and be encouraged not to burn crop residues. In contrast to the majority of farmers in Kenya and Tanzania, smallholder farmers in semi-arid Zimbabwe rely

Table 1. Variation in runoff (mm), soil loss (kg/ha) and grain production in response to the April-June 1997 seasonal rainfall of 502 mm. Embu, Kenya.

Treatment	spacing m	runoff mm	Soil loss kg/ha	Maize grain yield kg/ha
Control		136	3221	366.5
Fanya juu	15	nd[2]	7928	518.8
Large stone bund (0.6 m by 0.3 m)	15	Nd	14000	569.7
Small stone bund (0.3 m by 0.15 m)	15	62.6	2841	413.9
Large fixed trashline (0.6 by 0.3m - 3.6 t/ha stover)	15	58.7	3357	522.3
Large mobile trashline[1] (0.6 by 0.3m - 3.6 t/ha stover)	15	63	1156	561.5
Small mobile trashline[1] (0.3 by 0.15m - 1.8 t/ha stover)	15	78.7	1442	414.4
Small trashline (0.3 by 0.15m - 3.6 t/ha stover)	7.5	27.9	1442	571.1
Treatment s.e.d[#]		3.188***	1466**	106.8

Significant treatment difference - ** P<0.01: *** P<0.001.

1. Trashline is moved 3 m down slope at the start of each season, just prior to planting.
2. nd = no data.

Table 2. Economic analysis of maize on *Ngoro* and *Matuta* ridges with and without fertilizer. Tanzania

Conservation	Yield 2 kg/ha	Inputs		Gross margin per ha[4]		Returns to		Rank
		Labor [2] Days/ha	Materials[3] $	inc. labor $	exc. labor $	Cash[5]	Labor[6] $ per day	
Ngoro	1559	60	20	61	144	721%	2.40	3
Matuta ridge	1270	53	18	36	116	650%	2.20	4
Ngoro with fertilizer[1]	3745	62	164	151	229	139%	3.69	2
Matuta with fertilizer[1]	5162	55	175	287	267	210%	6.73	1

[1] Fertilizer includes 150 kg triple super phosphate and 50 kg Urea.
[2] Labor rates are based have been valued at tsh 1000 (US $1.50) per day.
[3] Materials include local seed varieties and packing material at 1997 market prices.
[4] Gross-margins have been calculated with and without the costs of labor, in order to show the effect of household supplied labor. Inc. = including; exc. = excluding.
[5] The value of gross income (yield*market prices) as a percentage of cash outlay (excluding household supplied labor).
[6] Gross-margin excluding labor costs divided by labor input.

Table 3. Farmers' views on the strengths and weaknesses of crop establishment and weeding technology options developed in Zimbabwe.

Practice		
Crop establishment	**Strengths**	**Weaknesses**
Third furrow planting	Combines plowing and planting, giving an overall saving in DAP and labor Ensures early weed control	Poor germination Higher labor and DAP than ripper and plow
Ripper and plow[1]	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	Ensures clean weeding	Labor intensive and back breaking
Cultivator	Labor saving and fast for interrow weeding	Weeds must be small Crop damage
Plow	Labor saving, smothers weeds, conserves moisture when ridges tied, promotes drainage in vleis	Crop damage May cause erosion if ridges are not tied

[1]Use of a ripper (a single narrow-tined animal-drawn implement); or a moldboard plow.

Table 4. Biomass production of live-barriers, kg ha^{-1} dry matter. Bolivia.

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

Note : P = Phalaris (*Phalarios tuberoarundinacea*); V = Vetiver (*Vetiveria zizanioides*); B = Broom (*Spartium junceum*); A = Atriplex (*Atriplex halimus*)

heavily on draft animal power (DAP) and ox-drawn moldboard plows for primary tillage and crop establishment. Seed is planted by hand into a furrow made by the plow and covered during the next pass, ensuring that the maize germinates into a relatively weed-free seedbed. Farmers face the problem that the peak demand for DAP coincides with the time that animals are in their weakest condition after a long dry season (Shumba et al., 1992). Achieving timely planting and good germination is particularly important, which can be difficult for those without access to adequate DAP. Farmers recognize the need for weed control to remove weeds, break any surface crust, and allow enhanced capture of rainfall. Weed management is a key component of conservation tillage (Norton, 1987; Riches et al., 1997) and with weeding accounting for up to 60% of the pre-harvest labor input for maize production (MLARR, 1992), considerable strain is placed on household labor. This can be reduced through the use of the ox-cultivator or plow.

Hence, the availability of labor, DAP and well-maintained, correctly used implements are key resources that determine the area planted, timeliness of operations, efficient utilization of other resources and hence the productivity and sustainability of the cropping system (Shumba et al., 1992; Ellis-Jones & Mudhara, 1997; Chatizwa, et al., 1998). The heterogeneity of household resource availability has been well established (Ellis-Jones and Mudhara, 1995; Scoones, 1995) and it is clear that farmers should have a range of technology options from which to select, based on individual socio-economic and biophysical conditions. Work over three seasons has provided opportunity for technology development with farmers in Zimuto Communal Farming Area and the adjacent Mshagashe Small Scale Commercial Farming Area to evaluate alternative crop establishment and weed control systems. This participatory approach to technology development has ensured that farmers have remained central to identifying, testing and evaluating the technology options (Twomlow et al., 1998a; Ellis-Jones et al., 1998b). The conclusion that can be drawn from the work is:

- Farmers have a deep understanding of the interrelationships of the factors, which need to be considered in achieving acceptable maize yields (Table 3).
- Farmers are willing to make a number of tradeoffs to achieve timely planting, crop stands and acceptable levels of weeding.
- On all soils planting into a furrow created with a ripper tine or a plow makes the best use of available draft animals and labor and produced the best maize yields. Both methods are better than the traditional farmer practice of the third furrow planting, dropping seed into the plow furrow to be subsequently covered by the next pass of the plow.
- Hand hoe weeding is better than both the ox-cultivator and ox-plow. The poor performance of the draft animal weeding methods is largely due to the poor condition of the farmers' implements and their lack of knowledge about their efficient use.
- Those households with low DAP and low labor are less willing to accept the tradeoff and see third furrow planting as less risky and a more appropriate method of saving both DAP and labor.

Conservation Through Participatory R&D in Latin America

SRI is working in three inter-Andean valley Provinces in Santa Cruz Department, and three in Cochabamba Department (at altitudes from 1800 - 4000 m asl), developing methods of participatory research with farm families (Sims and Bentley, 1998). The work concentrates on low-cost vegetative practices (live contour barriers and cover crops / green manures) and includes the selection and evaluation of grass, shrub and tree species for protective live-barriers; and legumes for fertility enhancement of the stabilized hillside soils. Technical and socio-economic evaluation of the options takes place primarily in the plots of farm families who are closely involved in decision-making and evaluation. The work in Bolivia, which was initiated in 1996, is a continuation of similar work undertaken with smallholder hillside farmers in Honduras (Sims, 1997). During initial farmer participatory appraisals of the hillside farming systems in the target communities it became clear that soil erosion and the consequent decline in soil fertility was resulting in a hillside plots being abandoned to fallow after two to three years. Because of the severity of the fertility decline, fallow periods can be up to 10 years. Farm families are concerned about this, especially where land is becoming an increasingly limiting production factor. The

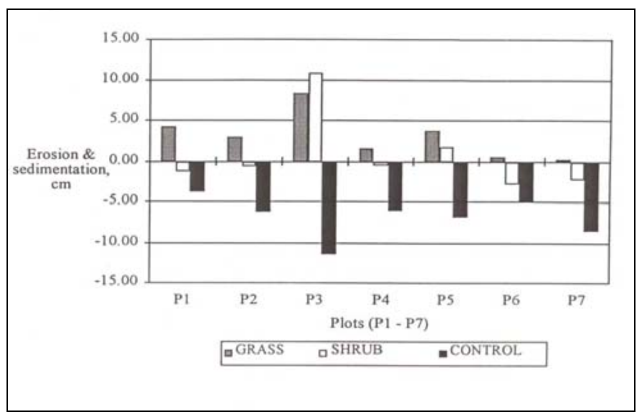

Figure 1. Sedimentation and erosion of soil with different live-barrier species, including Phalaris grass. Bolivia. The grasses used were: phalaris in plots 1, 2, 3, 4, 5, 6; and vetiver in plots 3 and 7. The shrubs only survived in four plots and were: broom in plots 3 and 5; atriplex in plots 6 and 7.

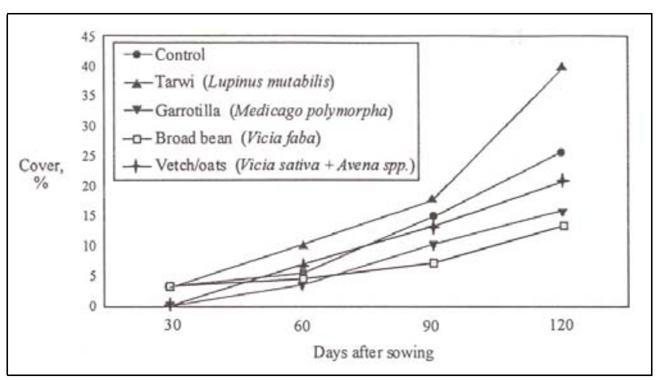

Figure 2. Rates of soil cover with four leguminous cover crop species. Bolivia.

chronic shortage of capital that is endemic in the hillside farming communities means that recommended soil and water conservation measures need to be centered around the low cost vegetative practices mentioned.

Initial results have shown that Phalaris grass (*Phalaris tuberoarundinacea*) has been an outstandingly adaptive and productive species. Previously unknown in the area, it has outperformed other grass and bush species in terms of barrier closure rate, terrace formation (Figure 1) and biomass production (Table 4) (Sims *et al.*, 1999). Initial reservations, from male household members, that the barriers occupied too much potential cropping space, were quickly overcome when the women pointed out the advantages of growing high quality fodder near to the homestead, crops were protected from the wind, and soil accumulation above the barriers served as a stark reminder of the constant sheet erosion taking place on unprotected plots.

The evaluation of leguminous cover crops has included rate of soil cover, biomass production and C:N ratio of the foliage. In a randomized block design four legumes were compared with a control of natural vegetation (Heredia-Vargas, 1998). Figure 2 indicates the relative merits of four species for soil cover and Table 5 gives yield comparisons of the same species. It was found that tarwi (*Lupinus mutabilis*) gave the best early-season soil cover and so reduced erosion. The same species also produced the highest biomass yield albeit with the highest C:N ratio.

Some of the main conclusions drawn from the work is:

- The Hillsides Project in Bolivia has demonstrated to farmers the effectiveness of live-barriers for soil protection with a range of plant species and under a rangeof agro climatic conditions. Phalaris grass, previously unknown in the Project area, has proved to be particularly successful.
- The participation of farm families in the research process has enabled them to appreciate the beneficial effects of barriers and observe the formation of terraces on their own plots. This has encouraged others to experiment with the practice.
- Moisture availability is a determining factor for the establishment of live-barriers and for the subsequent production of forage for livestock. Areas of higher moisture (with irrigation) and greater agricultural activity present the best conditions for the adoption of live-barriers.
- Tarwi is the legume best suited to the majority of conditions encountered in the Project focus areas for the improvement and protection of hillside soils. It produces abundant biomass and copes well with moisture stress which makes it possible to produce it under rainfed conditions and it develops adequately under conditions of poor soil fertility. It improves soil fertility as a result of incorporating its N rich biomass in the soil. It will probably also be shown to have a beneficial effect on soil physical properties.
- Under a tarwi cover crop, soil erosion is reduced to levels similar to the control (natural vegetation) where fallow conditions with no cultivation reduce soil losses.
- The degree of soil cultivation and the sowing method notably affect soil erosion, erosion control is best with crops sown in furrows (tarwi and broad bean) and worst with broadcast cover crops (vetch / oats and garrotilla).
- The establishment of cover crops for erosion control should, if soil moisture conditions allow, take place before the rainy season in order to achieve good cover and more stable soils when the rains start.

Factors affecting the adoption of conservation technologies

Although there are many technical measures available to reduce land degradation on smallholder hillside farms, unless there is sound understanding of the farming systems, farmers' decision making and adoption processes (Table 6), adoption is unlikely to occur.

The use of participatory technology development techniques, based on people centered extension that involves key stakeholders, with development incentives for land investment, will be an essential component of any development intervention. In considering new technologies, households will consider the socio-economic and biophysical resources at their disposal.

Land tenure of arable areas is not considered an issue where conservation techniques require an annual input and provide an immediate annual response. It may prove an issue where SWC requires an initial investment with returns arising over a number of seasons (Rukuni, 1994). In such cases investment and credit may be better secured through freehold title. However it has been argued that customary rights can provide this security (Moyo, 1995).

In the countries covered by this paper, the availability of labor and DAP are the key resources for crop production in small farm systems. They determine the area that is cropped, the timeliness of operations, the utilization of other inputs and therefore the productivity of the farming system.

The availability of labor is influenced by household composition, labor productivity and other claims on household time, notably household duties and off-farm work. Labor productivity is influenced by sex, age, nutritional status, health, food availability and off-farm income opportunities. Overall it is estimated that women contribute 60-80% of the labor for food crops (FAO, 1995) and even though cash crops are usually the responsibility of men, women provide much of the labor.

Female heads of households account for a significant proportion of rural households in sub-Saharan Africa (e.g. fifty percent in Zimbabwe [Chiduza, 1994]). The most vulnerable are those where the male adult is totally absent; they are prone to poverty with incomes less than 50% of male-headed households. This is in contrast to those households, where male migrants regularly send home remittances, which have the highest income levels.

The characteristics of soils that are related to their moisture holding capacity are associated with the risk and timeliness of carrying out tillage operations. Farmers have a range of crop establishment and weeding options available to them and will decide which to use based on the resources (DAP, labor and implements) available to them, soil type and condition, as well as their perceptions of risk and timeliness.

With the cropping period in most semi-arid regions being relatively short, the timing of field operations is critical. Conservation tillage offers potential for increasing productivity

(Elwell and Norton, 1988; Elwell, 1993), but adoption by farmers remains low (Sarapinda, 1990; EllisJones and Mudhara, 1995). Ongoing work in Zimbabwe is investigating the socio-economic factors affecting conservation tillage practices.

Households who do not practice sustainable systems will, in the long term, suffer increased poverty. There is no simple recipe such as low input agriculture or increased local participation; a combination of innovative approaches is required.

Table 5. Yield of dry matter, total N incorporated and C:N ratio of foliage of leguminous cover crops. Tirani. Cochabamba 1998.

Species	Dry matter ($kg\ ha^{-1}$)	Total N (%)	Total N incorporated ($kg\ ha^{-1}$)	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[1]	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 analysed.

[1]The control treatment is naturally invading weed vegetation.

Table 6. Preconditions necessary for household adoption of conservation technologies.

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

Source: Ellis-Jones and Mason, 1999

1. No = No adoption
2. Yes = possible adoption

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