Available online at www.sciencedirect.com
SCIENCE DIRECT®
Agriculture, Ecosystems and Environment 99 (2003) 61–81
Agriculture Ecosystems & Environment
www.elsevier.com/locate/agee

The case against direct incentives and the search for alternative approaches to better land management in Central America

J. Hellin[a,*], K. Schrader[b]

[a] *Geography Department, Oxford Brookes University, Oxford OX3 OBP, UK*
[b] *Center for Development and Environment (CDE), University of Berne, Hallerstrasse 12, CH-3012 Berne, Switzerland*

Received 29 April 2002; received in revised form 24 February 2003; accepted 1 April 2003

Abstract

Land shortages are forcing smallholder farmers to cultivate steeplands. Resulting accelerated soil erosion is being addressed by the promotion of soil and water conservation (SWC) technologies, such as cross-slope barriers. These are designed to reduce soil and water loss and increase productivity. Farmer adoption rates, however, are low and many development organisations have reverted to using direct incentives, such as cash payments and food-for-work, to attract participating farmers. Research in Central America shows that whilst these incentives stimulate implementation of SWC technologies, many of the farmers abandon the technologies once the direct incentives are withdrawn.

Field research from 1996 to 1998, involving farmed test plots on slopes greater than 33° sought to test a priori assumptions about the impact on soil loss and maize production following adoption of SWC technologies. Research demonstrates that at least one typical SWC technology—live barriers of *Vetiveria zizanioides* (vetiver grass)—has little or no impact on reducing soil loss or contributing to increased maize yields. This explains why, in the absence of direct incentives, few farmers adopt official recommendations: farmers see little benefit from their investment in the implementation and maintenance of SWC technologies. However, there are major off- and on-farm benefits to reduced soil loss and the research suggests that these benefits can be attained without the use of direct incentives, which are neither sustainable nor contribute to farmer empowerment. An alternative approach is to promote strategies that seek to combine farmers' concerns about productivity with conservationists' concerns about reducing soil erosion, often via soil cover management and an improvement in soil quality.

The alternative approach poses a challenge to development practitioners, politicians, and society in general. Firstly, a new professionalism is needed in which the interests of farmers are put first and where farmers' active participation in decision-making is encouraged. Secondly, farmers are more likely to practice better land management if they have secure access to land and receive favourable prices for agricultural products. These so-called indirect incentives are only likely to come about in the context of an enabling policy environment, created, in turn, by pressure from public and private institutions.

Keywords: Soil and water conservation; Incentives; Farmer adoption; Better land husbandry; Central America

* Corresponding author. Present address: No. 2 Kingston Barn Cottages, Kingston Farm, Chesterton, Leamington Spa, CV33 9LH, UK. Tel.: +44-1926-613252; fax: +44-1926-634401.
E-mail address: hellin@fincahead.com (J. Hellin).

0167-8809/$ – see front matter
doi:10.1016/S0167-8809(03)00149-X

1. Introduction

1.1. Land degradation and the threat to farmers' livelihoods

Land degradation is the aggregate diminution of the productive potential of the land, including its major uses (rainfed and irrigated arable, rangeland and forestry), its farming systems (e.g. smallholder subsistence), its ecological functions and its value as an economic resource (Blaikie and Brookfield, 1987). Central America is vulnerable to land degradation because of a combination of mountainous terrain and heavy rainfall (Leonard, 1987, p. 4; Lutz et al., 1994; Stonich, 1995; Hein, 1998, p. 128).

The dangers of land degradation are accentuated because inequalities in land distribution have forced smallholder farmers to cultivate the steepest slopes. Many of these farmers are dependent on a handful of subsistence crops such as maize and beans, along with periodic off-farm employment opportunities.

1.2. Responding to the crisis: SWC technologies and approaches

Faced with the danger that farmer-induced land degradation will undermine efforts to increase agricultural productivity on a sustainable basis, planners and policy-makers have invested in soil and water conservation (SWC) technologies. In the last 40–50 years, SWC programmes have been initiated in many parts of the developing world (Hudson, 1995, p. 354). A world-wide reduction in government support to rural areas in the 1990s has meant that SWC initiatives are largely promoted by non-governmental organisations (NGOs).

A variety of SWC technologies and approaches have been implemented world-wide including Central America (Lutz et al., 1994). The focus has been on controlling runoff and preventing soil loss (Young, 1989; Norman and Douglas, 1994, p. 55; Hurni et al., 1996, p. 20). Typically, cross-slope technologies such as live barriers, rock walls, infiltration ditches, terraces, and earth bunds have been promoted along with drainage channels and vegetated waterways. Recently, attention has been directed at no-burn policies and the use of cover crops, such as *Mucuna* spp., and conservation tillage systems (Anderson et al., 2001).

Most SWC initiatives have emphasised technology transfer, involving a small array of techniques. SWC programmes have sought to educate and involve the 'uninformed' farming communities and specialists have provided farmers with technical advice and assistance (Suresh, 2000).

1.3. Farmer adoption of SWC technologies and the use of incentives

One criterion often used to judge the success or failure of a SWC programme is the degree to which farmers adopt and/or adapt the technologies promoted. Based on this criterion, the results of many SWC projects world-wide have been disappointing (Blaikie, 1989; Hudson, 1992; Hinchclifffe et al., 1995, p. 3). In Central America, success stories of adoption, maintenance and adaptation of recommended SWC measures are, likewise, scarce (Schrader, 2002).

Bunch (1982, p. 59) and Chambers (1993) have pointed out that when farmers do not adopt recommended SWC technologies they are often accused of being ignorant, uncooperative, conservative and unwilling to change. This interpretation of farmers' behaviour stems from the fact that there is an abundance of literature that suggests that many SWC technologies do reduce soil loss and increase both productivity and production (Doolette and Smyle, 1990, p. 51; National Research Council, 1993). This published scientific research strengthens the official presumption that SWC specialists know best. Even though there are many reasons why farmers may not readily adopt SWC recommendations (Table 1), the conventional view is that farmers ought to be concerned about soil loss and ought to adopt SWC recommendations.

Governments and NGOs world-wide have often sought to stimulate farmer adoption of SWC technologies by offering a range of incentives (Kerr et al., 1996; Zaal et al., 1998; Giger et al., 1999). Incentives are 'any inducement on the part of an external agency (government, NGO or other), meant to both allow or motivate the local population, be it collectively or on an individual basis, to adopt new techniques and methods aimed at improving natural resource management' (Laman et al., 1996).

Table 1
Reasons for non-adoption and adaptation of SWC technologies

Farmers feel that they are unlikely to reap expected benefits because of a lack of secure access to land (Bunch, 1982, p. 45; Sanders, 1988; Comia et al., 1994; Wachter, 1994)
Labour costs involved in establishment and maintenance of technologies are too high, especially if farmers periodically work off-farm (de Janvry et al., 1989; Lal, 1989; Douglas, 1993; Zimmerer, 1993; Critchley et al., 1994; Stocking, 1995; Garrity et al., 1997)
Technologies do not reliably reduce soil loss and, even if they do, the reduction does not immediately raise yields (Pretty, 1995, p. 51)
Technologies of physical earthworks and cross-slope barriers do not, of themselves, lead to improvements in productivity (Critchley et al., 1994; Herweg and Ludi, 1999)
Technologies often require farmers to take land out of production and they are unwilling to do this (Fujisaka, 1991; Douglas, 1993; Pretty and Shaxson, 1998)
Farmers do not rate soil erosion as a key problem that needs to be addressed and so SWC recommendations are seen as a waste of time and effort (Ashby, 1985; Blaikie, 1989; Fujisaka, 1989; Rhoades, 1991, p. 40; Shaxson et al., 1997)
Resistance by local peoples to 'top–down' SWC programmes (Kloosterboer and Eppink, 1989; Robinson, 1989; Blaikie, 1993; Gardner and Lewis, 1996, p. 65)
Technologies exacerbate other problems such as water-logging, weeds, pests and diseases (Pretty, 1995, p. 51; Herweg and Ludi, 1999)
Technologies do not address, or may even increase, the risks inherent in agricultural production, especially if their implementation involves investment and additional debt (Napier and Sommers, 1993)
SWC practices require changes in farming systems that do not suit the economic or cultural realities of that system (Lutz et al., 1994)
Farmers do not feel that they own the technologies due to 'transfer-of-technology' extension practices (Dvorak, 1991; Enters and Hagmann, 1996; Pretty and Shah, 1997)

Most authors (e.g. Sanders et al., 1999), distinguish between direct and indirect incentives (see Fig. 1). The former includes cash payments for labour, grants, subsidies, loans, and also in kind payments such as the provision of food aid (food-for-work) and agricultural implements. Indirect incentives include fiscal and legislative measures such as tax concessions, secure access to land, and the removal of price distortions (Sanders and Cahill, 1999). In this article a similar distinction is made between direct and indirect incentives is made.

One of the justifications for offering incentives to farmers is that the incentives represent a legitimate payment for the off-site benefits of conservation that are enjoyed by society (Stocking and Tengberg, 1999). These benefits include reduced downstream siltation of reservoirs and impairment of aquatic ecosystems (Huszar, 1999). It is also argued that incentives at the beginning of a SWC programme are critical because farmers may not be able to afford investments in SWC, and the economic benefits of SWC, in terms of improved yields can be delayed for several years (Perich, 1993; Heissenhuber et al., 1998).

The provision of indirect incentives if often dependent on policy decisions made at central government level. SWC programmes run by private and public organisations are, therefore, unable to offer most indirect incentives and have tended to focus on the use of direct incentives.

In theory, once farmers are aware of the benefits of the SWC technologies, direct incentives can be phased out. However, whilst farmer implementation rates world-wide have been enhanced by these temporary subsidies, more often than not farmers abandon the technologies once external support is withdrawn (Herweg, 1993; Hurni et al., 1996; IFAD, 1996; Kerr et al., 1996; Pretty, 1998, p. 293). A similar phenomenon has been observed in Central America (Schrader et al., 1999).

Clearly, the prevailing conventional SWC approach is not working. Research in Central America, reported in this paper, sought to examine the effectiveness of the conventional SWC approach, with its focus on cross-slope technologies and use of direct incentives. Its aim was to determine some of the reasons why the current approach is not working and to identify an effective strategy for achieving a productive, conservation-effective and sustainable agriculture in steeplands. Research combined social surveys of farmer responses and attitudes to the use of direct incentives in SWC projects, interviews with project personnel, and replicated scientific measurements of both soil loss and maize production in a farm trial of a typical SWC technology (Hellin, 1999; Schrader, 2002).

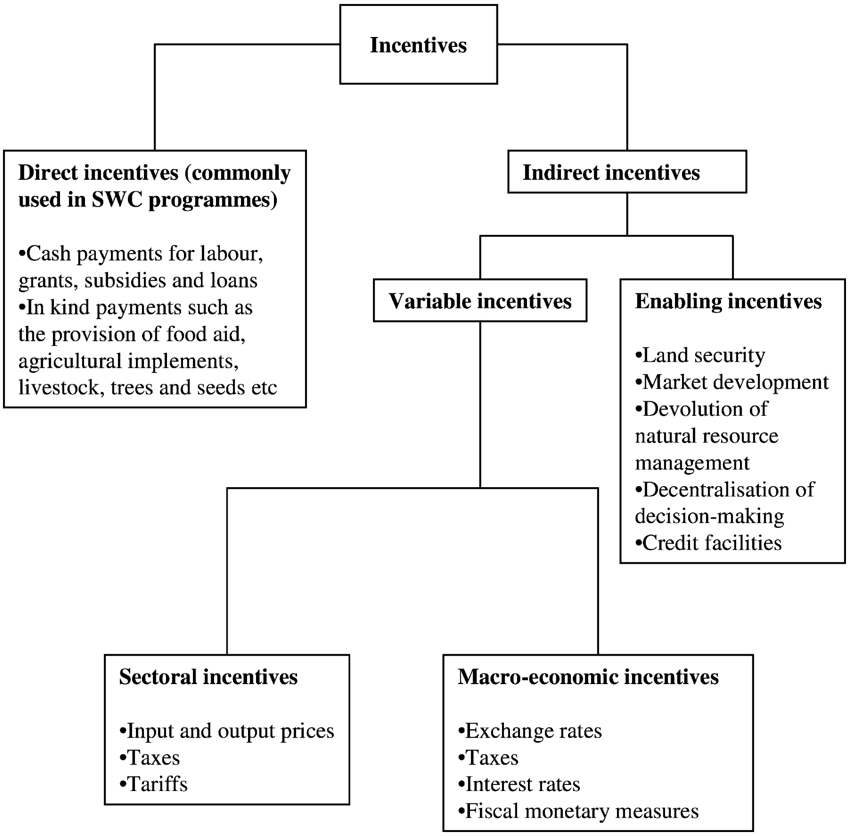

Fig. 1. Typology of incentives (based on Enters, 1999 and Sanders and Cahill, 1999).

2. A critique of the use of direct incentives in SWC projects

2.1. Use of direct incentives in Central America

In Central America, high rates of soil erosion reported in the literature (Table 2) have been used to justify the promotion of SWC technologies throughout the region. As part of this process, direct incentives have been widely used even though there have been few studies of their impact on the sustainable use of SWC initiatives and their contribution to better land management over more than a short-term period. The Swiss-funded Central American Programme for

Table 2
Reported erosion rates in Central America

In El Salvador, in an area with annual rainfall of 1900 mm, Sheng (1982) reports an annual soil loss of 127 t ha^{-1} on a field of bare soil with a 17° slope, planted with maize running up and down the slope
Annual soil loss measurements from north–west El Salvador on clay loam to clay soils on 20 m long plots with 17° slopes under traditional corn and bean cultivation range from 13 to 137 t ha^{-1} (Wall, 1981)
Wiggins (1981) reports annual soil loss rates of 15–150 t ha^{-1} on cultivated steeplands of the Acelhuate river basin in El Salvador
Research by Rivas (1993) in Nicaragua, documents annual soil losses of 78 t ha^{-1} from bare slopes of 9°
The Instituto Interamericano de Coorperación para la Agricultura (IICA) (1995) reports that serious erosion is affecting 170,000 ha in hillsides per year in Honduras with the rate of soil loss ranging from 22 to 46 t ha^{-1} per year

Sustainable Agriculture (PASOLAC) sought to rectify this situation and instigated a study of the impact of direct incentives on the adoption and adaptation of SWC technologies and practices (Schrader, 2002).

2.2. Materials and methods

The 3-year study was an iterative process. Guided interviews were carried out with 29 project personnel and technicians from 21 organisations in Honduras, Nicaragua and El Salvador, involved in SWC activities. PASOLAC staff considered these organisations to be the main actors in the promotion of sustainable land management in terms of the number of participating farmers. The list included public and private institutions as well as international and local organisations. A systematisation of the direct incentives used by these organisations was subsequently drawn up and four case study areas were identified—one in El Salvador and Honduras and two in Nicaragua—where so-called 'successful' agricultural, agroforestry and regional development projects with SWC components had been completed. The study areas had to meet a number of criteria detailed in Table 3.

The study sought to identify:

- the introduced SWC technologies that farmers implement and maintain;
- the reasons why farmers adopt or reject specific SWC technologies;
- the role that direct incentives play in farmer adoption.

Questionnaires were used in each of the case study areas and almost 500 smallholder farmer households were interviewed (Schrader, 2002). The following data were collected:

- type and number of SWC technologies established, maintained and abandoned;
- date of initial implementation and abandonment (if applicable) of the technologies;
- farmers' assessment of agricultural production with and without the technologies;
- farmers' descriptions of other positive and negative effects of the technologies;
- structure of the farm family;
- type of crops, cropping area, and the farm system;
- access to land and type of tenure;
- the labour situation on the farms and the farmers' main sources of income;
- type and quantity of incentives received;
- farmers' assessment of the advantages and disadvantages of each incentive.

In order to increase the reliability of data, a combination of research tools were used. After carrying out the questionnaire the research team visited each farmer's plots in order to verify some of the answers provided by the farmer, and also to describe the ecological conditions of the plots in terms of rainfall, temperature, slope, position, soil texture and soil depth. Towards the end of the data collecting process, results were presented at one international and five local workshops (Schrader, 2002). Subsequent meeting were held with donors, experts and field staff from the case study areas in order to discuss the results (PASOLAC/Intercooperation, 1998).

2.3. The impact of direct incentives on SWC

All of the 21 organisations interviewed have used direct material incentives to promote SWC and other land management practices. The most common approach has been the remuneration of farmers' labour costs with food, cash, and other material goods. In

Table 3
Criteria for selection of case study areas in Central America

Projects had to be located in hillsides
Projects had to have included at least a soil conservation and/or a sustainable agriculture component
At least one soil and water conservation technology measure had to have been promoted by using direct incentives
Farmers in the area had to have maintained at least one soil and water conservation technology
The project had to have finished and withdrawn direct incentives at least 3 years prior to the study
There had to be a local institution capable of collaborating in the study
Ex-project officials had to have considered the project a success with, at least initially, with high adoption rates of at least one soil and water conservation technology

almost all cases, credit on favourable terms has been offered to those who participated in the projects. In some cases the reforestation of communal or private land was also enhanced. For example, in a reforestation project in El Salvador, all the *Eucalyptus* spp. and *Tectona grandis* (teak) trees found on the farms included in the survey had been planted by participating farmers only when the project was offering direct incentives.

In the four case study areas, the use of direct incentives led to the establishment of SWC technologies such as stone walls, infiltration ditches and live barriers. For example, 80% of the farms surveyed in the Nicaragua study area established stone walls as part of a food-for-work programme. However, the case studies also demonstrated that once the direct incentives were withdrawn, farmers did not continue to establish the technologies, and existing structures were seldom maintained. Furthermore, Schrader (2002) has reported that in the absence of direct incentives there is little evidence of farmer adaptation of the SWC technologies nor of spontaneous diffusion.

The Honduran case study clearly demonstrates the impact of direct incentives on the establishment, maintenance and abandonment of SWC technologies. The Desarrollo Rural Integrado Marcala-Goascorán (DRI-MARGOAS) project in the department of La Paz ran from 1980 to 1991. SWC technologies were promoted from 1980 onwards, but direct incentives were used only from 1984 to 1991. These incentives included cash payments for participating farmers' labour input; free seedlings, barbed wire and fertiliser; and subsidised credit. Fig. 2 shows the establishment and maintenance rates of the two most heavily promoted SWC technologies—infiltration ditches and live barriers—and their abandonment once incentives were withdrawn. In the case of the infiltration ditches, 38% of the farms surveyed had infiltration ditches, and of those farmers who had established the technology, 79% confirmed having received cash for doing so.

Fig. 2 and the results from the three other case studies suggest that when farmers establish SWC technologies, their main objective is to gain access to the direct incentive being offered.

This is demonstrated by the increase in the length of SWC technologies maintained when direct incentives were introduced in 1984 and high abandonment rates following the removal of the incentives in 1991. Furthermore, most participating farmers established SWC technologies in a small plot in order to qualify for the incentives. Technologies were not established on the majority of farmers' cultivated land. For example, in the Honduras case study, recommended SWC technologies were implemented on only 14% of the total cropping area.

The fate of SWC technologies once direct incentives came to an end, contrasts sharply with the agronomic measures adopted by farmers in the DRI-MARGOAS project. The agronomic measures of no burning and contour cultivation were seldom promoted through the use of direct incentives but they proved to be more popular than structural SWC technologies. Fig. 3 shows that farmers continued to use these agronomic practices after the removal of direct incentives.

Schrader (2002) concluded that farmers response to SWC programmes is largely determined by the type of direct incentives used. Cash payments and food-for-work tended to stimulate the establishment of labour-intensive physical structures, such as stone walls and infiltration ditches. In contrast, the distribution of free seedlings or seed was often sufficient to encourage farmers to implement measures such as live barriers and planting crops on the contour.

One common theme in the case study areas was the promotion of pre-defined SWC technologies. Farmers had to follow technological prescriptions such as the dimensions of stone walls, and the spacing and species composition of live barriers irrespective of whether or not these complemented the farming system in terms of labour and land availability. There were also examples of where organisations, driven by the need to meet targets such as the establishment of a specified number technologies by a certain date, promoted SWC technologies in areas where there was little or no evidence of soil erosion.

2.4. Telling the farmers what to do

The need to show visible and quantitative results within the 3–5-year time-frame of many development projects means that there is little time for a detailed analyses of farmers' needs and the opportunities and limitations they face when making decisions about farm management. The tendency is for project personnel to arrive in rural communities with preconceived ideas of the erosion problem.

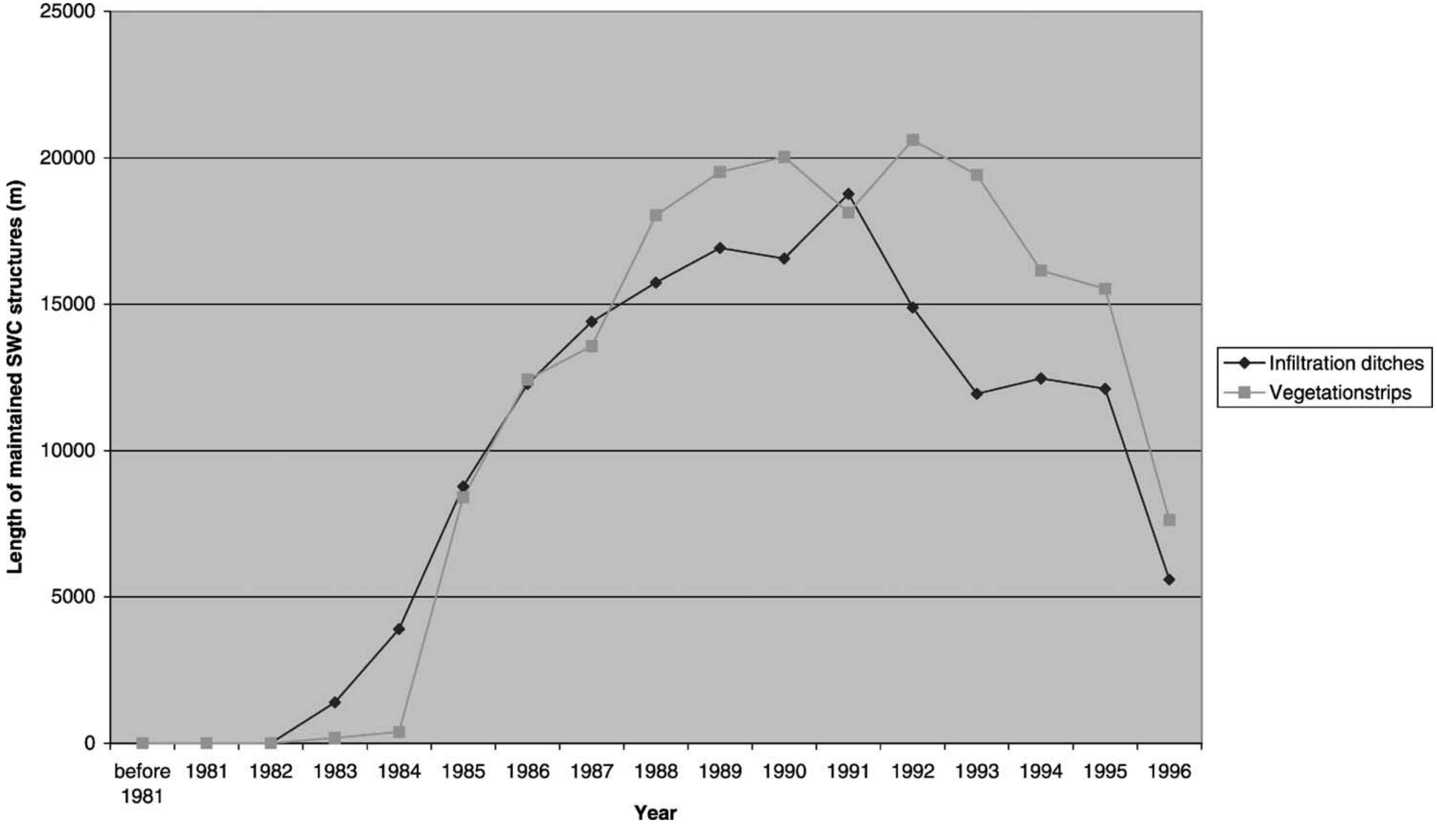

Fig. 2. Adoption and abandonment of structural SWC technologies in La Paz, Honduras. Project duration 1980–1991. Direct incentives provided 1984–1991. Number of farms = 147.

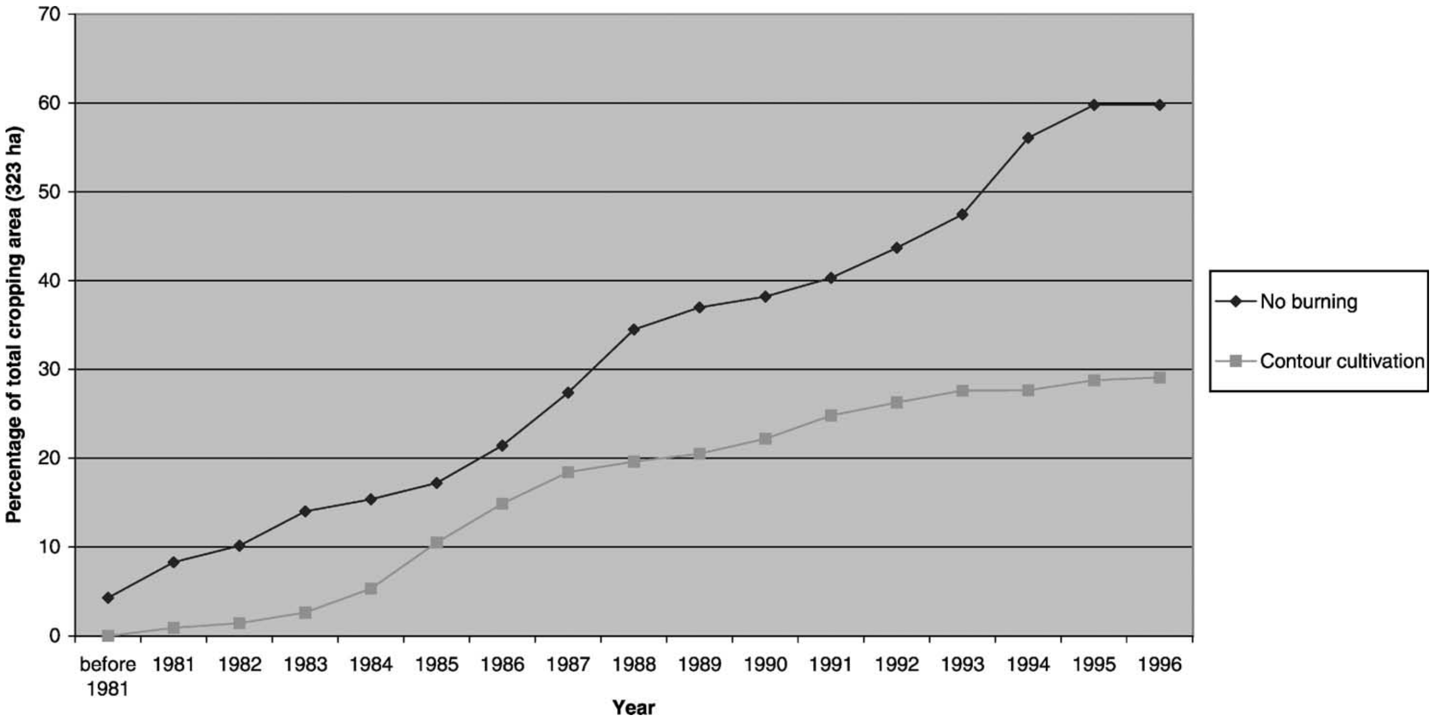

Fig. 3. Adoption and abandonment of agronomic measures in La Paz, Honduras. Project duration 1980–1991. Direct incentives provided 1984–1991. Number of farms = 147.

The widespread use of direct incentives facilitates the collaboration of hillside farmers and guarantees the implementation of a small choice of technologies, predominantly physical and mechanical structures, irrespective of whether or not they are appropriate to the agro-ecological, social and economic conditions faced by farmers. By doing so, projects are able to meet quantifiable targets but low diffusion rates and high abandonment rates, once direct incentives are removed, suggest that most recommended SWC measures:

- Do not contribute to resolving a problem or addressing a priority identified as such by participating farmers. These may include higher yields, better soil quality, improved water storage, reduced pest and diseases, fewer labour demands, and reduced inputs, etc.
- Cannot be implemented and/or maintained because of external or internal restrictions.

The absence of genuine farmer participation in designing SWC initiatives is evident in project documents. These highlight the extent to which a priori assumptions have been made about the need to control soil loss and the impact of SWC technologies on soil productivity. These assumptions may well be misplaced. Hellin and Haigh (2002a) report that in Honduras, farmers are not hugely worried by soil loss or by the possible off-site impacts of sediment washed from their fields. They are more concerned with the threats to productivity from pests and diseases and drought. In this context, farmers may well see SWC recommendations as irrelevant and misguided and may be acting rationally when they reject official recommendations or abandon them once direct incentives finish (Shaxson, 1997).

In the context of Central America is not clear to what extent soil erosion is a threat to farmers' livelihoods and whether it is in farmers' interests to adopt SWC technologies. Project reports from the four Central America case studies contain almost no information on the extent to which SWC technologies have contributed to an improvement in soil quality and yield enhancement, more sustainable land management, or improvements of households income. In order to fill this gap, research at a farmer-managed trial site in southern Honduras was designed to test the extent to which the conventional SWC approach is likely to contribute to an improvement in soil quality and an increase in production (Hellin, 1999).

3. Testing the effectiveness of SWC technologies

3.1. Challenging orthodox beliefs

SWC programmes have been based on the assumption that accelerated soil loss is the principal cause of land degradation. The rationale behind the promotion of conventional SWC technologies is based on the assumption that there is a direct relationship between soil erosion and productivity loss (Hillel, 1991, p. 161; Tengberg et al., 1998). In recent years this has been disputed (Shaxson, 1997). Research in Honduras sought to determine whether a widely promoted SWC technology—live barriers of *Vetiveria zizanioides* (vetiver grass)—makes any difference to soil loss or to agricultural production on the type of slopes being cultivated by smallholder farmers.

A large research literature suggests that vetiver grass barriers are effective in reducing soil loss and increasing productivity (e.g. World Bank, 1990; National Research Council, 1993; Grimshaw, 1995; Subudhi et al., 1998). What is less clear is whether the benefits are large enough to impress the farmer. Farmers are only likely to adopt recommendations for improved land management if they maintain or increase present output, confer other benefits important to them, and release resources, e.g. time, energy and cash, for other activities (Hudson, 1993b; Shaxson et al., 1989, p. 20; Douglas, 1999).

Increased yields alone may not be enough because higher costs incurred by farmers may negate most of the advantages of increases in production (Bunch, 1982, p. 60). For example, farmers with only 1 or 2 ha of land, struggling to produce sufficient food, cannot afford to take land out of food crop production in order to establish SWC technologies (Douglas, 1988). According to Hudson (1993b), a technology is only likely to be attractive to farmers if it offers a financial rate of return in the region of an increase of 50–100% in the first year. Despite the complexity of farmer decision-making vis-a-vis the adoption of SWC technologies, the impact of a technology on crop productivity is still an early indicator of its potential popularity.

There are two problems with much of the research that suggests that vetiver grass barriers are effective in reducing soil loss and increasing productivity. Firstly, the bulk of this work has been conducted on shallow slopes, often less than 11° and there is evidence that the effectiveness of live barriers to control soil loss is inversely related to slope angle (Young, 1997, p. 70). Secondly, much of the research comes from on-station rather than on-farm trials. The former are seldom representative of farming conditions found in steep marginal lands (Suppe, 1988).

There are, however, many advantages to on-station trials, notably the fact that it is easier to separate and control the variables (Hudson, 1993a, p. 2). One way to make on-station experiments more representative of on-farm conditions is to use a 'superimposed trial' that includes elements of management by both farmers and researchers, with implementation primarily the responsibility of farmers (Norman and Douglas, 1994, p. 10). This type of trial was established in southern Honduras (Hellin, 1999).

3.2. Methodology

Despite the use of the Universal Soil Loss Equation (USLE) plot size (4 × 22 m), there is no universally accepted standard design for agronomic exsperiments (Roels, 1985; Lal, 1994). A wide range of plot sizes and numbers of replications have been used in experiments world-wide (c.f. Omoro and Nair, 1993; Kiepe, 1995; Ruppenthal et al., 1996; Turkelboom et al., 1997; McDonald et al., 2002). Hudson (1993a, p. 35) argues that there is little justification for following the precise measurements, in metric units, of the USLE plot size and advocates a plot size of approximately 5 m × 20 m and a minimum of three replications.

The results reported here came from a trial in southern Honduras that consisted of 12 research plots each measuring 24 m × 5 m. The plots were established in a mid-slope position on a 33–37° slope that was cleared of secondary forest. Research, therefore, took place on land typical of that currently being brought into cultivation. Soil characteristics are summarised in Table 4. A 0.5 m deep drainage channel was constructed above each of the plots and the upper and lateral borders of each plot were bounded by metal sheeting to prevent surface leakage underneath and overtopping.

Table 4
Soil characteristics at the trial site in southern Honduras (from Hellin and Haigh, 2002a)

Soil type	Fine-loamy to coarse-loamy gypsic, isohyperthermic Ustropepts (Inceptisol) and Haplustolls
Soil texture	Sandy loam with an average particle size distribution of sand (62%), silt (21%) and clay (17%)
Topsoil	Depths ranged from 18 to 45 cm
Bulk density	Ranged from 1.06 to 1.37 g cm^3 at 0–8 cm depths and 1.08–1.42 g cm^3 at 8–16 cm depths
Infiltration	Rates varied from 17 to 783 mm h^{-1} with an average of 398 mm h^{-1}
Organic carbon	Ranged from 1.62 to 2.26% in topsoil
pH values	Ranged from 5.1 to 6.5 in topsoil
CEC values	Varied between 11.49 and 15.36 $cmol_c$ kg^{-1} in topsoil

There were two agricultural treatments, each replicated six times: one set with live barriers of vetiver grass and a control set without barriers. The treatments were assigned randomly to each plot. Toness et al. (1998, p. 36) report that, because of land taken out of production, a spacing of approximately 6.0 m between SWC technologies is the minimum distance that is acceptable to farmers in Honduras. At the trial site, live barriers were established at 6.0 m intervals, i.e. there were three barriers per plot. Single row barriers were used and vetiver splits were planted at a distance of 3–5 cm.

At the trial site and based on agronomic research reported in the literature (e.g. Lal, 1989; Rüttiman et al., 1995; Kiepe, 1996), collecting barrels were used for four of the plots. Runoff was channelled into a calibrated barrel with an overflow pipe that delivered 1/8 of the volume to a second barrel. A permeable cloth in the first barrel separated the sludge from the supernatant. After each runoff event the amount of water in the recipients was measured. Soil loss was determined by calculating the dry weight of the sludge and taking a 1 l aliquot sample which was then filtered.

In the remaining eight plots, and based on Howeler (1994) and Hudson (1995, p. 162), runoff was channelled into plastic-lined catch-pits. Each catch-pit measured 2.0 m in depth × 1.5 m × 1.5 m. Small holes were punctured in the plastic to allow the runoff to dissipate slowly. The sediment load was collected at the end of each growing season.

Following local practice, farmers planted maize in the research plots twice a year. The *primera* (first crop) is sown at the start of the May–October rainy season; the *postrera* (second crop) is sown in September towards the end of the main rains and harvested in January. Maize used at the site was the local variety. The research team enforced a uniform and standardised planting density of 32 rows per plot across all 12 plots. In live barrier plots, therefore, no land was lost to agricultural production. In the assessment process, maize yields were calculated for each crop row by weighing the maize cobs with a hand balance and multiplying this by the average dry weight of maize grains per cob. Maize data from the lowest and uppermost four rows in the plot were not included in the analysis.

The experiment lasted for 3 years (1996–1998) and was terminated by landslide activity caused by Hurricane Mitch (Hellin and Haigh, 1999). Maize data were collected from five harvests because the third year's *postrera* crop was destroyed by the hurricane. Catch-pit sediment data for 1998 were also lost during the same event.

3.3. Summarised results of soil loss and maize yields

Soil loss records from the barrels and catch-pits showed a high level of variability in both control and live barrier plots. In 1996, total soil loss per plot ranged from 9.8 to 41.8 t ha^{-1}; in 1997 from 0.5 to 1.8 t ha^{-1} and in pre-Mitch 1998 from 0.7 to 1.8 t ha^{-1}. In 1997, low soil loss figures were due to reduced rainfall and fewer intense storms due to *El Niño*, while in 1998 (pre-Mitch) reduced soil loss was due to increased ground cover (Hellin, 1999). Rainfall characteristics, recorded by a tipping-bucket rain gauge (ELE DRG-52), are summarised in Table 5 along with total rainfall in the 3 years prior to the start of the experiment. The average annual soil loss by erosion was around 17 t ha^{-1} (data for 1998 are pre-Hurricane Mitch).

There were no significant differences between soil loss from live barrier and control plots. Live barriers break up the slope and so reduce the capacity of runoff to move soil particles down the slope. There should, therefore, be less soil movement between live barriers and mobilised soils should be trapped up-slope of the barriers. Soil augur measurements towards the end of the experiment show, as expected, deposition of soil above the barriers (Hellin, 1999). They also demonstrated that scouring occurred below the barrier. The deposition and scouring effect was not evident in the control plots. This compensation was sufficient to ensure that, if the live barriers made any difference to overall soil loss from the plots, it was not detectable within the time-frame of this study.

Farmers are not particularly concerned about soil loss per se. Their interest in adopting and adapting SWC technologies is greater where those SWC technologies clearly contribute to increased production. Much research literature suggests that vetiver grass barriers do lead to an increase in soil productivity (Greenfield, 1989; Doolette and Smyle, 1990, p. 51; National Research Council, 1993; Laing, 1992; Bharad, 1995; Rao and Rao, 1996; Pawar, 1998; Subudhi et al., 1998). Contrary to this literature, the results from the trial site show that there were no significant differences in maize yields from control and live barrier plots for the 3-year period 1996–1998 or for each of the years 1996, 1997 and 1998 (Fig. 4).

Table 5
Rainfall characteristics at the trial site in southern Honduras

	1993	1994	1995	1996	1997	1998
Total rainfall (mm)	1379	1426	2527	3037	1614	2218
Rainfall intensity (J/m^2)[a]	na	na	na	31252	16076	30875

Data do not include rainfall during and after Hurricane Mitch that struck Honduras at the end of October, 1998. Rainfall characteristics during the Hurricane are reported by Hellin (1999). From Hellin and Haigh (2002a).

[a] Hudson (1995, p. 79) defines an intensity of 25 mm h^{-1} as a practical threshold separating erosive from non-erosive rain. In Table 5, rainfall intensity is based on erosive rainfall events where rainfall intensities equalled or were greater than 25 mm h^{-1} for any 10 min interval during the storm. Calculations are based on Hudson (1995, p. 81). The few rainfall events for which erosivity data are missing (due to an error in the automated rain gauge) have been omitted.

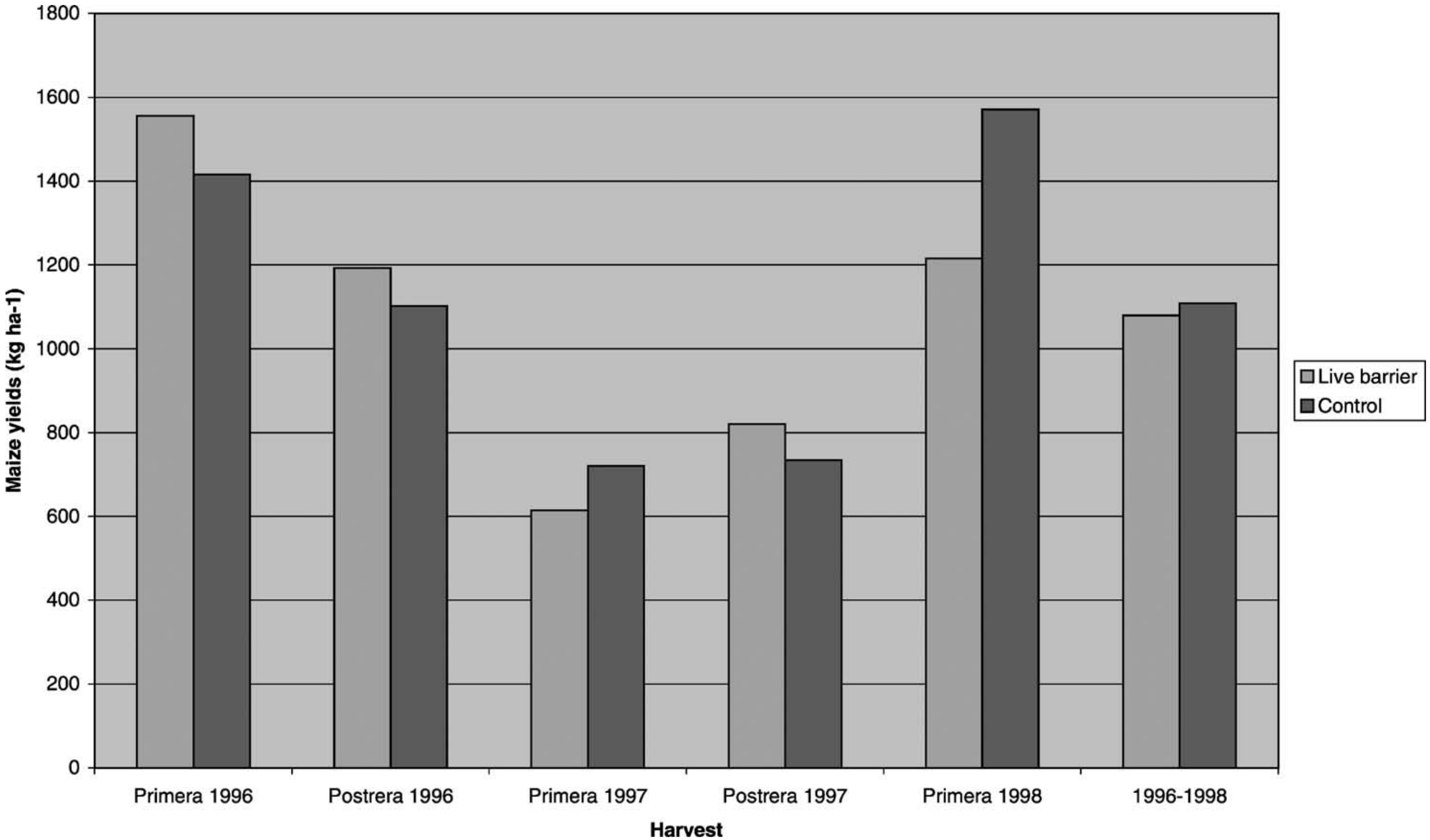

Fig. 4. Treatment and maize yields in kg ha^{-1} from 1996 to 1998.

This despite the fact that a uniform maize density was used across all plots. Over a 3-year period the average yield per harvest was 1109 kg ha^{-1} on the control plots and 1080 kg ha^{-1} on the live barrier plots (Hellin, 1999).

Farmers would be more inclined to adopt and maintain SWC technologies, such as live barriers, if the technologies provided sufficient and obvious benefits in terms of increased or more secure production. These benefits do not exist, at least in the life-time of the experiment. The research findings suggest that farmers may be acting rationally when they either do not adopt recommended technologies or do so only when direct incentives are offered, only to abandon the technologies when the incentives are removed.

4. The search for alternatives approaches to achieving SWC

4.1. Soil erosion and productivity

Soil erosion is seen as a threat to farmers' livelihoods because of the assumed link between soil loss and productivity (FAO, 1995, p. 5). The reality, however, is that the relationship between soil loss and productivity is elusive at best (Schiller et al., 1982; Alegre and Rao, 1996; Herweg and Ludi, 1999). Crop yields are determined by the complex interaction of a number of factors including soil quality, crop and land management system, and climate (Clark, 1996, p. 14; Enters, 1998, p. 8).

The impact of climate on yields is illustrated by results from the trial site. Smallholder farmers are primarily concerned with harvest-by-harvest production. In 1997, maize yields at the trial site were almost 50% less than in 1996 (Fig. 4). The low maize yields in 1997 were more overtly related to reduced rainfall caused by *El Niño* than soil erosion in 1996. This conclusion is supported by the fact that in 1998, above average rainfall meant that *primera* maize yields were significantly greater than those of the *primera* 1997 and similar to the *primera* in 1996. Given such variation in crop yields, the farmers' 'failure' to identify soil erosion as a threat to their livelihoods seems reasonable.

The focus on controlling soil loss may be misplaced because crop productivity is governed more by the quality of soil remaining on the land than the amount of soil removed through erosion (Shaxson et al., 1997, p. 26). Soil quality is largely affected by the way in which the land is managed and a reduction in soil quality, partly characterised by declining soil structure and loss of effective pore-spaces within the soil, may have a much more detrimental effect on plant growth than the erosional loss of soil particles (Norman and Douglas, 1994, p. 7).

Soil compaction and the loss of soil organic matter do tend to accelerate erosion, but this soil loss indicates that the land has already been degraded and soil quality has diminished. The problem with the conventional SWC approach is that, by focusing on keeping soils within a field rather than enhancing the quality of soil in those fields, it treats a symptom rather than the cause of poor land management.

4.2. Live barriers and scouring

The focus on capturing eroded soil as opposed to enhancing soil quality has meant that many SWC technologies are seldom as effective as anticipated. Cross-slope SWC structures, such as live barriers, do retain soil and water, and yields may indeed rise in areas where eroded soil is retained. However, the technologies do little to improve soil quality in the inter-row areas. At the trial site in Honduras, soil accumulated and crop yields increased, albeit marginally, in narrow strips where soil was retained immediately up-slope of the barriers. However, these gains were made at the expense of soil losses and reduced crop yields from below the barriers, where erosion exposed infertile subsoil (Hellin and Haigh, 2002b).

Similar patterns of skewed crop yields due to the scouring and deposition effect in live barrier treatments has been reported in the Philippines (Garrity, 1996; Garrity et al., 1997) and in Ethiopia (Herweg and Ludi, 1999). This redistribution of soil between live barriers is accentuated by agricultural practices such as field preparation, weeding and harvesting (Govers et al., 1994; Lewis and Nyamulinda, 1996; Turkelboom et al., 1997; Nehmdahl, 1999; Quine et al., 1999). Redistribution of soil caused by the scouring effect could be reduced by having the live barriers more closely spaced (McDonald et al., 2002) but very few farmers would accept a further reduction in the cropping area.

4.3. Better land husbandry and soil quality

Conventional SWC technologies address neither the fundamental physical cause of soil erosion, which is soil degradation due to poor land management, nor the central purpose of the farmers' activities, which is to gain the maximum livelihood benefit from the land through agricultural production. They also neglect the complex of socio-economic constraints that affect the farmer's land management decision-making to the detriment of effective soil loss mitigation.

An alternative approach to effective soil and water management is the 'Better Land Husbandry' (BLH) movement (Shaxson, 1997; Hellin and Haigh, 2002a). This approach aims to tackle the primary causes of land degradation, which are those practices that lead to a reduction in soil quality. The farmer, rather than the SWC expert or extension agent, is granted centre stage. As a result, the starting point for improved land management is the farmer's concerns of agricultural productivity and its sustainability. This is achieved through the preservation and improvement of soil quality (van Breeman, 1993; Altieri, 2002; Doran, 2002).

The BLH approach seeks to identify and promote agricultural practices that at best cure and at worst avoid the problems that lead, first to land degradation (via a deterioration in soil quality) and later to accelerated erosion which is caused by the degraded soil's reduced ability to absorb and retain water. The aim is to identify practices that meet the needs of the farmers as well as those of soil conservation and that, as a result, will become incorporated as normal agricultural routine. Instead of SWC being seen as the precursor to increasing crop yields, BLH argues that SWC is achieved more effectively and acceptably as a side-effect of soil improvement. When soil quality is enhanced, improved production goes hand in hand with reduced soil erosion (Hudson, 1988).

5. Better land husbandry in practice: agro-ecological, social and economic implications

5.1. Agro-ecological considerations

From the agro-ecological perspective, BLH involves the use of agronomic, biological and mechanical practices to improve soil quality via soil protection, incorporation of organic matter, and the use of soil organisms. The onset of soil erosion is a consequence of decreased cover of the soil, which allows high-energy rainfall to impact the soil surface directly, and of reduced porosity in the surface layers which causes more runoff (Shaxson et al., 1997). Hence, soil structure that favours root growth also favours better water relations in the soil and the conservation of soil and water in situ (Shaxson, 1993). Any farming practice is conservation-effective if it promotes and maintains the soil in optimum condition for water acceptance and plant growth.

BLH addresses those most critical factors controlled by the land user: surface cover and soil structure (Foster et al., 1982; Lal, 1988; Shaxson, 1992; Kellman and Tackaberry, 1997, p. 264). Improvements in crop husbandry, such as early planting, optimum density, leaving crop residues on the surface can reduce erosion, enhance water infiltration and, through improving soil quality, lead to improved crop production (Sillitoe, 1993; Stocking, 1994; Gardner and Mawdesley, 1997).

The use of cover crops such as *Mucuna* spp. in Central America and the expansion of zero tillage systems in Argentina, Brazil and Paraguay, are testament to the extent to which improved soil structure and infiltration capacity can achieve advances in both production and conservation (Shaxson, 1988; Buckles et al., 1998; de Freitas, 2000, pp. 33–38).

5.2. Farmers as part of the solution rather than the problem

Most SWC programmes have viewed farmers as part of the problem rather than part of the solution (Hudson, 1988; Shaxson et al., 1989, p. 13; Enters and Hagmann, 1996). As a consequence, farmers have more often been addressed as targets than as collaborators or the ultimate decision-makers. Unless farmers are enabled to express their priorities and, through participation, to direct research and extension into avenues that support their needs, the technologies provided to them, as is the case in many SWC programmes, are liable to be inappropriate (Chambers, 1993).

The BLH approach puts the farmer first and encourages the farmers to take charge of their lives and to solve their own problems by involvement and innovation (Bunch, 1982; Edwards, 1989). It begins by addressing the farmer's situation, identifying which of the farmers' existing practices are beneficial from a conservation point of view and which are not, along with the farmers' reasons for practising them (Douglas, 1993). SWC professionals can then work with farmers in improving the conservation-effectiveness of their land management practices.

5.3. A new professionalism

The BLH approach requires an holistic analysis of the farming system and seeks to discover an integrated framework within which land management issues can be analysed and practical, and productivity-enhancing, economic and conservation-effective strategies can be formulated and implemented. The current negativity of the soil loss prevention mentality is exchanged for an ethos that focuses on positive aspects of land management.

Active farmer participation is central to this holistic approach to better land management (CDE, 1995; CDE, 1998; Hurni and Ludi, 2000). One of the obstacles to active participation is that SWC professionals often fail to appreciate the complexity of farmers' realities. Consequently, these professionals opt for 'simplicity' and make recommendations that are not relevant to farmers' multi-faceted problems (Bunch, 1982; Hudson, 1993b; Shaxson et al., 1997). In part, this is the outcome of an educational and training system that favours the production of narrowly specialised technical experts, who may find it hard to see the farmer's 'big picture' (Chambers, 1993; Doran et al., 1996).

Farmers' realities are such that they need assistance from 'an ecology of disciplines' working together rather than advice from single-disciplinary professionals. Sound soil conservation is site- and problem-specific and must be adapted by the farmers so that they can integrate it into their farming systems (Shaxson, 1993; Herweg, 1996). Farmers need time to experiment with different practices, validate some of these practices, and adapt them to local conditions. The decision as to which practices are most appropriate should be made by the farmers themselves and not by project staff. A more holistic approach to better land management, therefore, requires a new professionalism for soil conservation workers, agricultural scientists and extension agents, a professionalism with new concepts, values, methods and behaviour (Pretty and Chambers, 1994; Doran et al., 1996).

6. The role of incentives in better land management

The use of direct incentives in order to win over farmers' participation in SWC programmes is a powerful and tempting tool, but it is a very dubious instrument for achieving the mid- and long-term goals of sustainable land use and efficient natural resource management. Direct incentives create dependency in rural communities (Bunch, 1982). This, in turn, undermines key components of human development, namely participatory decision-making, empowerment of marginal groups and farmer experimentation (Hinchclifffe et al., 1995; Steiner, 1996; Schrader, 2002). SWC programmes should wherever possible avoid the use of direct incentives (Giger, 1999).

In some cases there may be some justification for encouraging farmers to adopt SWC practices (e.g. to avoid down-stream flooding or sedimentation). In this context a more effective strategy is to promote practices that enhance soil quality. There are more likely to be popular with farmers because they are likely to lead to an improvement in productivity (Sanders et al., 1999), and represent changes or improvements of the farming system rather than non-productive add-ons that characterise many structural SWC measures. There are a number of examples world-wide where better land husbandry approaches that focus on improving soil quality have led to the conservation of water and soil and an increase in productivity (Cheatle, 1993; Bunch and López, 1995; de Freitas, 2000; Pretty and Hine, 2001). Few if any direct incentives were used in these cases.

One of the greatest incentives to better land management is likely to be the creation of an enabling environment, one which includes secure access to land, seeds, markets, along with favourable prices for agricultural inputs and products, and access to professional extension services and education (Almekinders, 2002). These indirect incentives are a critical component of efforts to reduce land degradation. They are also the sort of incentives that are often ignored by NGOs and other organisations working in rural development because they are largely outside their remit. The provision of indirect incentives if often dependent on policy decisions made at central government level. This underlines the important roles that government policy and macro-economics play in determining the outcome of land management decisions (Sanders and Cahill, 1999).

7. Conclusions

Land degradation is a social, economic, political, and technical problem requiring multi- and inter-disciplinary solutions. Research in Central America demonstrates that by focusing on soil loss rather than soil quality, cross-slope soil conservation technologies are unlikely to contribute to increased production. Understandably, farmers consider such technologies largely irrelevant. As a result many SWC programmes have encouraged farmer participation by offering direct incentives. Whilst these have led to the establishment of technologies, farmers have tended to abandon the technologies once the incentives are withdrawn.

A new approach is needed which aspires to introduce land management changes that improve soil quality while simultaneously meeting the farmers' needs. Despite the numerous constraints to better land management, farmers can improve soil quality via the use of conservation-effective and productivity-enhancing technologies. An approach best articulated by BLH. In this context there is little need for direct incentives. Local farmers should be encouraged to identify which land management practices best complement their farming systems. This can be done by supporting farmers and other stake-holders in finding specific solutions to land management problems via participatory approaches such as farmer field schools (FFS) and/or participatory appraisal and monitoring methods.

Whilst it is not a panacea to land degradation, an approach that encourages better land husbandry has the potential to draw social and natural scientists into productive dialogue with the land users, leading to practical and realistically sustainable land management development initiatives. A new approach is a major challenge to the development community because it entails the empowerment of rural families and the building of democratic and transparent institutions.

Acknowledgements

This paper is an output from research funded by the United Kingdom Department for International Development (DFID) for the benefit of developing countries (R6292CB Forestry Research Programme), the United States Agency for International Development (USAID) Soil Management Collaborative Research Support Program (Grant No. LAG-G-00-97-00002-00) and the Swiss Agency for Development and Co-operation (SDC). The views expressed here are not necessarily those of DFID, USAID or SDC. The authors wish to thank two anonymous reviewers, Dr. de Rouw (Department of Agronomy, INRA, France) and Prof. Martin Haigh (Oxford Brookes University) for their invaluable comments on earlier versions of this paper.

References

Alegre, J.C., Rao, M.R., 1996. Soil and water conservation by contour hedging in the humid tropics of Peru. Agric. Ecosyst. Environ. 57, 17–25.

Almekinders, C.J.M., 2002. Incentive measures for sustainable land use and conservation of agrobiodiversity. In: Proceedings of a Workshop on Experiences and Lessons from Southern Africa, Lusaka, Zambia, 11–14 September 2001. Southern African Development Community Plant Genetic Resources Centre (SPGRC).

Altieri, M.A., 2002. Agroecology: the science of natural resource management for poor farmers in marginal environments. Agric. Ecosyst. Environ. 93, 1–24.

Anderson, S., Gündel, S., Pound, B., Triomphe, B., 2001. Cover Crops in Smallholder Agriculture: Lessons from Latin America. Intermediate Technology Development Group Publishing, London.

Ashby, J.A., 1985. The social ecology of soil erosion in a Colombian farming system. Rural Sociol. 50 (3), 377–396.

Bharad, G.M., 1995. Vetiver hedges on contour for in-situ rain water management on arable, non-arable and wet lands. Newslett. Vetiver Network 13, 32–34.

Blaikie, P., 1989. Explanation and policy in land degradation and rehabilitation for developing countries. Land Degrad. Rehabil. 1, 23–37.

Blaikie, P., 1993. What glasses are we wearing? Different views of environmental management. In: Christiansson, C., Dahlberg, A., Loiske, V.-M., Östberg, W. (Eds.), A Discussion on Natural Resources Research in the Third World. School of Geography, Stockholm University, pp. 32–35.

Blaikie, P., Brookfield, H., 1987. Land Degradation and Society. Methuen, London.

Buckles, D., Triomphe, B., Sain, G., 1998. Cover Crops in Hillside Agriculture: Farmer Innovation with Mucuna. International Development Research Centre, Ottawa, Canada.

Bunch, R., 1982. Two Ears of Corn. A Guide to People-Centered Agricultural Improvement. World Neighbors, Oklahoma City.

Bunch, R., López, G., 1995. Soil Recuperation in Central America: Sustaining Innovation after Intervention, vol. 55. Gatekeeper Series, International Institute for Environment and Development, London.

Center for Development and Environment (CDE), 1995. Sustainable Use of Natural Resources. A Conceptual Approach to Sustainable Management of Natural Resources in the Context of Development. Development and Environment Reports No. 14, Center for Development and Environment, Berne.

Center for Development and Environment (CDE), 1998. Auto-Didactic Learning for Sustainability (ALS). A Concept for Auto-Didactic Training in Sustainable Use of Natural Resources for Development Personnel. Center for Development and Environment, Berne.

Chambers, R., 1993. Challenging the Professions. Frontiers for Rural Development. Intermediate Technology Publications, London.

Cheatle, R.J., 1993. Next steps towards better land husbandry. In: Hudson, N.W., Cheatle, R. (Eds.), Working with Farmers for Better Land Husbandry. Intermediate Technology Publications, London, pp. 223–230.

Clark, R., 1996. Methodologies for the Economic Analysis of Soil Erosion and Conservation. Working Paper GEC 96-13, Centre for Social and Economic Research on the Global Environment. University of East Anglia, Norwich.

Comia, R.A., Paningbatan, E.P., Håkansson, I., 1994. Erosion and crop yield response to soil conditions under alley cropping systems in the Philippines. Soil Tillage Res. 31, 249–261.

Critchley, W.R.S., Reij, C., Willcocks, T.J., 1994. Indigenous soil and water conservation: a review of the state of knowledge and prospects for building on traditions. Land Degrad. Rehabil. 5, 293–314.

de Freitas, V.H., 2000. Soil Management and Conservation for Small Farms: Strategies and Methods of Introduction, Technologies and Equipment, vol. 77. FAO Soils Bulletin, Rome.

de Janvry, A., Sadoulet, E., Young, L.W., 1989. Land and labour in Latin American agriculture from the 1950s to the 1980s. J. Peasant Stud. 16 (3), 396–424.

Doolette, J.B., Smyle, J.W., 1990. Soil and moisture conservation technologies: review of literature. In: Doolette, J.B., Magrath, W.B. (Eds.),Watershed Development in Asia: Strategies and Technologies. World Bank Technical Paper 127, pp. 35–69.

Doran, J.W., 2002. Soil health and global sustainability: translating science into practice. Agric. Ecosyst. Environ. 88 (2), 119–127.

Doran, J.W., Sarrantonio, M., Liebig, M.A., 1996. Soil health and sustainability. Adv. Agron. 52, 1–54.

Douglas, M.G., 1988. Integrating conservation into farming systems: the Malawi experience. In: Moldenhauer, W.C., Hudson, N.W. (Eds.), Conservation Farming on Steeplands. Soil and Water Conservation Society and World Association of Soil and Water Conservation, Ankeny, Iowa, pp. 215–227.

Douglas, M.G., 1993. Making conservation farmer-friendly. In: Hudson, N.W., Cheatle, R. (Eds.), Working with Farmers for Better Land Husbandry. Intermediate Technology Publications, London, pp. 4–15.

Douglas, M.G., 1999. Productive and conservation-effective better land husbandry practices. Newslett. Assoc. Better Land Husbandry 10, 44–50.

Dvorak, K.A., 1991. Methods of on-farm, diagnostic research on adoption potential of alley cropping. Agrofor. Syst. 15, 167–181.

Edwards, M., 1989. The irrelevance of development studies. Third World Q. 11 (1), 116–135.

Enters, T., 1998. Methods for the Economic Assessment of the On- and Off-Site Impacts of Soil Erosion, Issues in Sustainable Land Management, vol. 2. International Board for Soil Research and Management, Bangkok.

Enters, T., 1999. Incentives as policy instruments—key concept and definitions. In: Sanders, D.W., Huszar, P.C., Sombatpanit, S., Enters, T. (Eds.), Incentives in Soil Conservation: From Theory to Practice. Oxford & IBH Publishing, New Delhi, pp. 25–40.

Enters, T., Hagmann, J., 1996. One-way, two-way, which way? Extension workers: from messengers to facilitators. Unasylva 46 (184), 1–9.

Food and Agriculture Organisation (FAO), 1995. Agricultural Investment to Promote Improved Capture and Use of Rainfall in Dryland Farming. FAO Investment Centre Technical Paper No. 10, Rome.

Foster, G.R., Moldenhauer, W.C., Wischmeier, W.H., 1982. Transferability of U.S. technology for prediction and control of erosion in the tropics. In: Kussow, W., El-Swaify, S.A., Mannering, J. (Eds.), Soil Erosion and Conservation in the Tropics, vol. 43. American Society of Agronomy Special Publication, Soil Science Society of America, Madison, Wisconsin, pp. 135–149.

Fujisaka, S., 1989. The need to build upon farmer practice and knowledge: reminders from selected upland conservation projects and policies. Agrofor. Syst. 9, 141–153.

Fujisaka, S., 1991. Improving productivity of an upland rice and maize system: farmer cropping choices or researcher cropping pattern trapeziods. Exp. Agric. 27, 253–261.

Gardner, K., Lewis, D., 1996. Anthropology, Development and the Post-Modern Challenge. Pluto Press, London.

Gardner, R., Mawdesley, K., 1997. Soil erosion in the Middle Mountains of Nepal. Agrofor. Forum 8 (4), 25–29.

Garrity, D.P., 1996. Tree–soil–crop interactions on slopes. In: Ong, C.K., Huxley, P. (Eds.), Tree–Crop Interactions: A Physiological Approach. CAB International, Wallingford, Oxon, International Centre for Research in Agroforestry, Kenya, pp. 299–318.

Garrity, D.P., Stark, M., Mercado, A., 1997. Rapid soil distribution within alleys: why simple extension models for contour hedgerows may not be appropriate. Agrofor. Forum 8 (4), 5–7.

Giger, M., 1999. Avoiding the Shortcut: Moving Beyond the Use of Direct Incentives. A Review of Experiences with the Use of Incentives in Projects for Sustainable Soil Management. Development and Environment Reports 17, Centre for Development and Environment, Berne.

Giger, M., Liniger, H., Critchley, W., 1999. Use of direct incentives and profitability of soil and water conservation in eastern and southern Africa. In: Sanders, D.W., Huszar, P.C., Sombatpanit, S., Enters, T. (Eds.), Incentives in Soil Conservation: From Theory to Practice. Oxford & IBH Publishing, New Delhi, pp. 247–274.

Govers, G., Vandaele, K., Desmet, P., Poesen, J., Bunte, K., 1994. The role of tillage in soil redistribution on hillslopes. Eur. J. Soil Sci. 45, 469–478.

Greenfield, J.C., 1989. Vetiver Grass (*Vetiveria* spp.) the Ideal Plant for Vegetative Soil and Moisture Conservation. The World Bank, Washington, DC.

Grimshaw, R.G., 1995. Vetiver grass—its use for slope and structure stabilisation under tropical and semi tropical conditions. In: Barker, D.H. (Ed.), Vegetation and Slopes: Stabilisation, Protection and Ecology. Institute of Civil Engineers, Thomas Telford, London, pp. 26–35.

Hein, W., 1998. Unterentwicklung. Krise der Peripherie. Phänomene-Theorien-Strategien. Grundwissen Politik, Band 20. Leske + Budrich, Opladen.

Heissenhuber, A., Kantelhardt, J., Pahl, H., 1998. Economic Considerations Concerning the Possibilities of Environmental Protection in Agriculture. Medit 3/98, Edagricole, Bologna, pp. 4–10.

Hellin, J., 1999. Soil and Water Conservation in Honduras: A Land Husbandry Approach. Ph.D. Dissertation, Oxford Brookes University, Oxford.

Hellin, J., Haigh, M.J., 1999. Rainfall in Honduras during Hurricane Mitch. Weather 50 (11), 350–359.

Hellin, J., Haigh, M.J., 2002a. Better land husbandry in Honduras: towards the new paradigm in conserving soil, water and productivity. Land Degrad. Dev. 13, 1–18.

Hellin, J., Haigh, M.J., 2002b. Impact of Vetiveria zizanioides (vetiver grass) live barriers on maize production in Honduras. In: Wang, L., Wu, D., Tu, X., Nie, J. (Eds.), Proceedings of the 12th International Soil Conservation Organisation Conference on Sustainable Utilization of Global Soil and Water Resources, 26–31 May 2002, vol. 3. Beijing, China, pp. 277–281.

Herweg, K., 1993. Problems of acceptance and adaptation of soil conservation in Ethiopia. In: Baum, E.E., Wolff, P., Zöbisch, M.A. (Eds.), Acceptance of Soil and Water Conservation. Strategies and Technologies. Topics in Applied Resource Management in the Tropics, vol. 3. German Institute for Tropical and Subtropical Agriculture (DITSL), Witzenhausen, pp. 391–411.

Herweg, K., 1996. Field Manual for Assessment of Current Erosion Damage. Soil Conservation Research Programme and Centre for Development and Environment, Berne.

Herweg, K., Ludi, E., 1999. The performance of selected soil and water conservation measures—case studies from Ethiopia and Eritrea. Catena 36, 99–114.

Hillel, D., 1991. Out of the Earth: Civilization and the Life of the Soil. University of California Press, Berkeley.

Hinchclifffe, F., Guijt, I., Pretty, J.N., Shah, P., 1995. New Horizons: The Economic, Social and Environmental Impacts of Participatory Watershed Development, vol. 50. Gatekeeper Series, International Institute for Environment and Development, London.

Howeler, R.H., 1994. Integrated soil and crop management to prevent environmental degradation in cassava-based cropping systems. In: Bottema, J.W.T., Stolz, D.R. (Eds.), Proceedings of Workshops on Upland Agriculture in Asia, Bogor, Indonesia, 6–8 April 1993, pp. 195–224.

Hudson, N.W., 1988. Tilting at windmills or fighting real battles. In: Moldenhauer, W.C., Hudson, N.W. (Eds.), Conservation Farming on Steeplands. Soil and Water Conservation Society and World Association of Soil and Water Conservation, Ankeny, Iowa, pp. 3–8.

Hudson, N.W., 1992. Land Husbandry. BT Batsford Limited, London.

Hudson, N.W., 1993a. Field Measurement of Soil Erosion and Runoff, vol. 64. FAO Soils Bulletin, Rome.

Hudson, N.W., 1993b. Soil and water management for the nineties—new pressures, new objectives. In: Hudson, N.W., Cheatle, R. (Eds.), Working with Farmers for Better Land Husbandry. Intermediate Technology Publications, London, pp. 15–20.

Hudson, N.W., 1995. Soil Conservation. BT Batsford Limited, London.

Hurni, H., Ludi, E., 2000. Reconciling Conservation with Sustainable Development. A Participatory Study Inside and Around the Simen Mountains National Park, Ethiopia. Center for Development and Environment, Berne.

Hurni, H., International Group of Contributors, 1996. Precious Earth: From Soil and Water Conservation to Sustainable Land Management. Centre of Development and Environment (CDE), International Soil Conservation Organisation (ISCO), Berne.

Huszar, P.C., 1999. Justification for using soil conservation incentives. In: Sanders, D.W., Huszar, P.C., Sombatpanit, S., Enters, T. (Eds.), Incentives in Soil Conservation: From Theory to Practice. Oxford & IBH Publishing, New Delhi, pp. 57–68.

Instituto Interamericano de Cooperación para la Agricultura (IICA) and La Dirección de Planeamiento, Programación, Proyectos y Auditoría Técnica (DIPRAT), 1995. Honduras-Diagnóstico del sector agropecuario. IICA, San José, Costa Rica.

International Fund of Agricultural Development (IFAD), 1996. Combating Desertification—The Role of Incentives. A Desk-Review of Literature and Practical Experiences with Incentives in Natural Resources Management in Sub-Saharan Africa; with Emphasis on the Gender, Institutional and Policies Dimensions. IFAD & Centre for Development Co-operation Services (CDCS), Vrije Universiteit, Amsterdam.

Kellman, M., Tackaberry, R., 1997. Tropical Environments: The Functioning and Management of Tropical Ecosystems. Routledge, London.

Kerr, J.M., Sanghi, N.K., Sriramappa, G., 1996. Subsidies in Watershed Development Projects in India: Distortions and Opportunities, vol. 61. Gatekeeper Series, International Institute for Environment and Development, London.

Kiepe, P., 1995. Effect of Cassia siamea hedgerow barriers on soil physical properties. Geoderma 66, 113–120.

Kiepe, P., 1996. Cover and barrier effect of Cassia siamea hedgerows on soil conservation in semi-arid Kenya. Soil Technol. 9, 161–171.

Kloosterboer, E.H., Eppink, L.A.A.J., 1989. Soil and water conservation in very steep areas—a case study of Santo Antão Island, Cape Verde. In: Baum, E.E., Wolff, P., Zöbisch, M.A.

(Eds.), The Extent of Soil Erosion—Regional Comparisons. Topics in Applied Resource Management in the Tropics, vol. 1. German Institute for Tropical and Subtropical Agriculture, Witzenhausen, pp. 111–142.

Laing, D., 1992. Correspondence. Newslett. Vetiver Network 8, 13–14.

Lal, R., 1988. Soil erosion research on steeplands. In: Moldenhauer, W.C., Hudson, N.W. (Eds.), Conservation Farming on Steeplands. Soil and Water Conservation Society, Ankeny, Iowa, pp. 45–53.

Lal, R., 1989. Agroforestry systems and soil surface management of a tropical alfisol. Agrofor. Syst. 8, 1–6.

Lal, R., 1994. Soil erosion by wind and water: problems and prospects. In: Lal, R. (Ed.), Soil Erosion Research Methods. Soil and Water Conservation Society, Ankeny, Iowam, pp. 1–9.

Laman, M., Sanders, H., Zaal, F., Sidikou, H.A., Toe, E., 1996. Combatting Desertification—The Role of Incentives. Centre for Development Cooperation Services, Vrije Universitiet, Amsterdam.

Leonard, H.J., 1987. Natural Resources and Economic Development in Central America: A Regional Environmental Profile. International Institute for Environment and Development, Washington, DC.

Lewis, L.A., Nyamulinda, V., 1996. The critical role of human activities in land degradation in Rwanda. Land Degrad. Dev. 7, 47–55.

Lutz, E., Pagiola, S., Reiche, C., 1994. Economic and Institutional Analyses of Soil Conservation Projects in Central America and the Caribbean. World Bank Environment Paper No. 8, Washington, DC.

McDonald, M., Healey, J.R., Stevens, P.A., 2002. The effects of secondary forest clearance and subsequent land-use on erosion losses and soil properties in the Blue Mountains of Jamaica. Agric. Ecosyst. Environ. 92, 1–19.

Napier, T.L., Sommers, D.G., 1993. Soil conservation in the tropics: a prerequisite for societal development. In: Baum, E.E., Wolff, P., Zöbisch, M.A. (Eds.), Acceptance of Soil and Water Conservation. Strategies and Technologies. Topics in Applied Resource Management in the Tropics, vol. 3. German Institute for Tropical and Subtropical Agriculture (DITSL), Witzenhausen, pp. 7–28.

National Research Council, 1993. Vetiver Grass: A Thin Green Line Against Erosion. National Academy Press, Washington, DC.

Nehmdahl, H., 1999. Vetiver grass in a soil and water conservation trial—Tanzania. Newslett. Vetiver Network 20, 47–49.

Norman, D., Douglas, M., 1994. Farming Systems Development and Soil Conservation. FAO Farm Systems Management Series, Rome.

Omoro, L.M.A., Nair, P.K.R., 1993. Effects of mulching with multipurpose-tree prunings on soil and water run-off under semi-arid conditions in Kenya. Agrofor. Syst. 22, 225–239.

Programa para una agricultura sostenible en las laderas de América Central (PASOLAC)/Intercooperation, 1998. Marco orientador para un manejo adecuado de incentivos en la promoción de una agricultura sostenible. Project Report, Managua, Tegucigalpa, San Salvador.

Pawar, P.B., 1998. Prospect and Problems in Use of Vetiver for Watershed Management in Sub Mountain and Scarcity Zones (Maharashtra, India). Newslett. Vetiver Network 19, 33–35.

Perich, I., 1993. Umweltökonomie in der entwicklungspolitischen Diskussion. Ansätze und Perspektiven. Berichte zur Entwicklung und Umwelt Nr. 8, Gruppe für Entwicklung und Umwelt, University of Berne.

Pretty, J.N., 1995. Regenerating Agriculture: Policies and Practice for Sustainability and Self-Reliance. Earthscan Publications, London.

Pretty, J.N., 1998. The Living Land: Agriculture, Food and Community Regeneration in Rural Europe. Earthscan Publications, London.

Pretty, J.N., Chambers, R., 1994. Towards a learning paradigm: new professionalism and institutions for agriculture. In: Scoones, I., Thompson, J. (Eds.), Beyond Farmer First: Rural People's Knowledge, Agricultural Research and Extension Practice. Intermediate Technology Publications, London, pp. 182–202.

Pretty, J.N., Hine, R., 2001. Reducing Food Poverty with Sustainable Agriculture: A Summary of New Evidence. University of Essex, Colchester.

Pretty, J.N., Shah, P., 1997. Making soil and water conservation sustainable: from coercion and control to partnerships and participation. Land Degrad. Dev. 8, 39–58.

Pretty, J.N., Shaxson, T.F., 1998. The potential of sustainable agriculture. Newslett. Assoc. Better Land Husbandry 8, 4–21.

Quine, T.A., Walling, D.E., Chakela, Q.K., Mandiringana, O.T., Zhang, X., 1999. Rates and patterns of tillage and water erosion on terraces and contour strips: evidence from caesium-137 measurements. Catena 36, 115–142.

Rao, C.N., Rao, M.S., 1996. Effect of vetiver hedge on runoff, soil loss, soil moisture and yield of rainfed crops in Alfisol watersheds of southern India. Newslett. Vetiver Network 15, 21–22.

Rhoades, R.E., 1991. The Art of the Informal Agricultural Survey, vol. 36. International Institute of Tropical Agriculture Research Guide, Ibadan, Nigeria.

Rivas, D.A., 1993. Factors Affecting Soil Erosion in Maize (Zea mays L.) and Pineapple (Ananas comosus L.) Stands in Ticuantepe, Nicaragua: A Preliminary Evaluation of the Universal Soil Loss Equation Using Data from Erosion Plots. M.Sc. Dissertation, Reports and Dissertations No. 15, Swedish University of Agricultural Sciences.

Robinson, D.A., 1989. Motives and policies for soil conservation in colonial and early, post-independence Zambia. In: Baum, E.E., Wolff, P., Zöbisch, M.A. (Eds.), The Extent of Soil Erosion—Regional Comparisons. Topics in Applied Resource Management in the Tropics, vol. 1. German Institute for Tropical and Subtropical Agriculture, Witzenhausen, pp. 87–109.

Roels, J.M., 1985. Estimation of soil loss at a regional scale based on plot measurements—some critical considerations. Earth Surf. Processes Landforms 10, 587–595.

Ruppenthal, M., Leihner, D.E., Hilger, T.H., Castillo, F.J.A., 1996. Rainfall erosivity and erodibility of Inceptisols in the southwest Colombian Andes. Exp. Agric. 32, 91–101.

Rüttiman, M., Schaub, D., Prasuhn, V., Rüegg, W., 1995. Measurement of runoff and soil erosion on regularly cultivated

fields in Switzerland—some critical considerations. Catena 25, 127–139.
Sanders, D.W., 1988. Food and Agriculture Organization activities in soil conservation. In: Moldenhauer, W.C., Hudson, N.W. (Eds.), Conservation Farming on Steeplands. Soil and Water Conservation Society, Ankeny, Iowa, pp. 54–62.
Sanders, D., Cahill, D., 1999. Where incentives fir in soil conservation programs. In: Sanders, D.W., Huszar, P.C., Sombatpanit, S., Enters, T. (Eds.), Incentives in Soil Conservation: From Theory to Practice. Oxford & IBH Publishing, New Delhi, pp. 11–24.
Sanders, D.W., Huszar, P.C., Sombatpanit, S., Enters, T. (Eds.), 1999. Incentives in Soil Conservation: From Theory to Practice. Oxford & IBH Publishing, New Delhi.
Schiller, J.M., Anecksamphant, C., Sujanin, S., 1982. Development of areas of shifting cultivation in north Thailand: "Thai-Australia land development project". In: Kussow, W., El-Swaify, S.A., Mannering, J. (Eds.), Soil Erosion and Conservation in the Tropics. American Society of Agronomy Special Publication No. 43, Soil Science Society of America, Madison, Wisconsin, pp. 77–96.
Schrader, K., 2002. Anreize zur nachhaltigen Bodennutzung in Zentralamerika. Eine Analyse direkter materieller Anreize in Projekten der ländlichen Regionalentwicklung in Bergregionen El Salvadors, Honduras' und Nicaraguas. Geographica Bernensia G 69, Institute of Geography, University of Berne.
Schrader, K., Ulloa, S., García Valenzuela, A., 1999. Producción y conservación: Adopción de un paquete tecnológico en Condega, Estelí, Nicaragua. In: Sain, G. (Ed.), La adopción de tecnologías. La perspectiva del agricultor y sus implicaciones para la elaboración de políticas. Instituto Interamericano de Cooperación para la Agricultura (IICA), San José, Costa Rica, pp. 231–237.
Shaxson, T.F., 1988. Conserving soil by stealth. In: Moldenhauer, W.C., Hudson, N.W. (Eds.), Conservation Farming on Steeplands. Soil and Water Conservation Society and World Association of Soil and Water Conservation, Ankeny, Iowa, pp. 9–17.
Shaxson, T.F., 1992. Crossing some watersheds in conservation thinking. In: Tato, K., Hurni, H. (Eds.), Soil Conservation for Survival. Soil and Water Conservation Society in Co-operation with the International Soil Conservation Organisation and the World Association of Soil and Water Conservation, Ankeny, Iowa, pp. 81–89.
Shaxson, T.F., 1993. Conservation-effectiveness of farmers' actions: a criterion of good land husbandry. In: Baum, E.E., Wolff, P., Zöbisch, M.A. (Eds.), Acceptance of Soil and Water Conservation: Strategies and Technologies. Topics in Applied Resource Management in the Tropics, vol. 3. German Institute for Tropical and Subtropical Agriculture, Witzenhausen, pp. 103–128.
Shaxson, T.F., 1997. Soil erosion and land husbandry. Land Husbandry 2 (1), 1–14.
Shaxson, T.F., Hudson, N.W., Sanders, D.W., Roose, E., Moldenhauer, W.C., 1989. Land Husbandry: A Framework for Soil and Water Conservation. Soil and Water Conservation Society, Ankeny, Iowa.
Shaxson, T.F., Tiffen, M., Wood, A., Turton, C., 1997. Better Land Husbandry: Re-thinking Approaches to Land Improvement and the Conservation of Water and Soil, Natural Resource Perspectives, vol. 19. Overseas Development Institute, London.
Sheng, T.C., 1982. Erosion problems associated with cultivation in humid tropical hilly regions. In: Kussow, W., El-Swaify, S.A., Mannering, J. (Eds.), Soil Erosion and Conservation in the Tropics. American Society of Agronomy Special Publication No. 43, Soil Science Society of America, Madison, Wisconsin, pp. 27–39.
Sillitoe, P., 1993. Losing ground? Soil loss and erosion in the highlands of Papua New Guinea. Land Degrad. Rehabil. 4, 143–166.
Steiner, K., 1996. Causes of soil degradation and development approaches to sustainable soil management. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), Margraf Verlag, Eschborn.
Stocking, M., 1994. Assessing vegetative cover and management effects. In: Lal, R. (Ed.), Soil Erosion Research Methods. Soil and Water Conservation Society, Ankeny, Iowa, pp. 211–232.
Stocking, M., 1995. Soil erosion and land degradation. In: O'Riordan, T. (Ed.), Environmental Science for Environmental Management. Longman, Harlow, pp. 223–242.
Stocking, M., Tengberg, A., 1999. Soil conservation as an incentive enough—experiences from southern Brazil and Argentina on identifying sustainable practices. In: Sanders, D.W., Huszar, P.C., Sombatpanit, S., Enters, T. (Eds.), Incentives in Soil Conservation: From Theory to Practice. Oxford & IBH Publishing, New Delhi, pp. 69–86.
Stonich, S., 1995. Development, rural impoverishment, and environmental destruction in Honduras. In: Painter, M., Durham, W.H. (Eds.), The social causes of environmental destruction in Latin America. The University of Michigan Press, pp. 63–99.
Subudhi, C.R., Pradhan, P.C., Senapati, P.C., 1998. Effect of grass bunds on erosion loss and yield of rainfed rice—Orissa, India. Newslett. Vetiver Network 19, 32–33.
Suppe, F., 1988. The limited applicability of agricultural research. Agric. Hum. Values 5 (4), 4–14.
Suresh, R., 2000. Soil and Water Conservation Engineering. Standard Publishers, New Delhi.
Tengberg, A., Stocking, M., Dechen, S.C.F., 1998. Soil erosion and crop productivity research in South America. In: Blume, H.-P., Eger, H., Fleischhauer, E., Hebel, A., Reij, C., Stenier, K.G. (Eds.), Towards Sustainable Land Use: Furthering Cooperation Between People and Institution. Adv. Geoecol. 31, 355–362.
Toness, A.S., Thurow, T.L., Sierra, H., 1998. Sustainable Management of Tropical Hillsides: An Assessment of Terraces as a Soil and Water Conservation Technology. United States Agency for International Development Soil Management Collaborative Research Support Program, Technical Bulletin No. 98-1, University of Texas, Texas.
Turkelboom, F., Poesen, J., Ohler, I., van Keer, K., Ongprasert, S., Vlassak, K., 1997. Assessment of tillage erosion rates on steep slopes in northern Thailand. Catena 29, 29–44.
van Breeman, N., 1993. Soils as biotic constructs favouring net primary productivity. Geoderma 57, 183–211.

Wachter, D., 1994. Land titling: possible contributions to farmland conservation in Central America. In: Lutz, E., Pagiola, S., Reiche, C. (Eds.), Economic and Institutional Analyses of Soil Conservation Projects in Central America and the Caribbean. World Bank Environment Paper No. 8, Washington, DC, pp. 150–157.

Wall, J.R.D. (Ed.), 1981. A Management Plan for the Acelhuate River Catchment, El Salvador: Soil Conservation, River Stabilisation and Water Pollution Control. Land Resources Development Centre, Overseas Development Administration, UK.

Wiggins, S., 1981. A case study in cost–benefit analysis: soil conservation in the Rio Acelhuate river basin, El Salvador. In: Morgan, R. (Ed.), Soil Conservation. Wiley, Chichester, pp. 399–417.

World Bank, 1990. Vetiver Grass: The Hedge Against Erosion. The World Bank, Washington, DC.

Young, A., 1989. The potential of agroforestry for soil conservation and sustainable land use. In: Baum, E.E., Wolff, P., Zöbisch, M.A. (Eds.), The Extent of Soil Erosion—Regional Comparisons. Topics in Applied Resource Management in the Tropics, vol. 1. German Institute for Tropical and Subtropical Agriculture, Witzenhausen, pp. 35–55.

Young, A., 1997. Agroforestry for Soil Management. CAB International, Wallingford.

Zaal, F., Laman, M., Sourang, C.M., 1998. Resource Conservation or Short Term Food Needs? Designing Incentives for Natural Resource Management, Issue Paper No. 77. International Institute for Environment and Development, London.

Zimmerer, K., 1993. Soil erosion and labour shortages in the Andes with special reference to Bolivia, 1953–91: implications for ‘conservation-with-development’. World Dev. 21 (10), 1659–1675.