LAND DEGRADATION & DEVELOPMENT
Land Degrad. Develop. **29**: 962–974 (2018)
Published online 7 October 2015 in Wiley Online Library (wileyonlinelibrary.com) **DOI**: 10.1002/ldr.2429

ECONOMIC BENEFITS AND COSTS OF SUSTAINABLE LAND MANAGEMENT TECHNOLOGIES: AN ANALYSIS OF WOCAT'S GLOBAL DATA

Markus Giger[1]*, Hanspeter Liniger[1], Caspar Sauter[2], Gudrun Schwilch[1]
[1]*Centre for Development and Environment, University of Bern, Bern, Switzerland*
[2]*Institute of Economic Research, University of Neuchâtel, Neuchâtel, Switzerland*

Received: 19 November 2014; Revised: 18 August 2015; Accepted: 18 August 2015

ABSTRACT

Perceived profitability is a key factor in explaining farmers' decision to adopt or not adopt sustainable land management (SLM) technologies. Despite this importance, relatively little is known about the economics of SLM. This paper contributes to the literature by analysing data on costs and perceived cost/benefit ratios of SLM technologies. Data are taken from the World Overview of Conservation Approaches and Technologies technology database and cover 363 case studies conducted in a variety of countries between 1990 and 2012. Based on an in-depth descriptive analysis, we determine what costs accrue to local stakeholders and assess perceived short-term and long-term cost/benefit ratios. Our results show that a large majority of the technologies in our sample are perceived as being profitable: 73% were perceived to have a positive or at least neutral cost/benefit ratio in the short term, while 97% were perceived to have a positive or very positive cost/benefit ratio in the long term. An additional empirical analysis confirms that economic factors are key determinants of land users' decisions to adopt or not adopt SLM technologies. We conclude that a wide range of existing SLM practices generate considerable benefits not only for land users, but for other stakeholders as well. High initial investment costs associated with some practices may, however, constitute a barrier to their adoption; short-term support for land users can help to promote these practices where appropriate. Copyright © 2015 John Wiley & Sons, Ltd.

KEY WORDS: sustainable land management; costs; benefits; perceived cost benefit ratio; technologies

INTRODUCTION

Land degradation due to mismanagement, overuse and abuse of natural resources is a global problem (Zhao *et al*., 2013; Mandal & Sharda, 2013; Angassa, 2014; Laudicina *et al*., 2015; Ligonja *et al*., 2015), potentially leading to a loss of ecosystem services (Keesstra *et al*., 2012; Zhang *et al*., 2013; Berendse *et al*., 2015; Papanastasis *et al*., 2015), and is considered to be a policy challenge of global dimensions (Brevik *et al*., 2015). The concept of sustainable land management (SLM) was introduced in the early 1990s as a response to land degradation (Smyth & Dumanski, 1993) and has been promoted ever since. SLM encompasses soil, water and vegetation conservation measures and is based on the key principles of enhancing the productivity and protection of natural resources while being economically viable and socially acceptable (Schwilch *et al*., 2014). Although the need for SLM strategies is widely accepted within the scientific community (Novara *et al*., 2013; Batjes *et al*., 2014; Tejada & Benítez, 2014; van Leeuwen *et al*., 2015; Mekonnen *et al*., 2015; Ndah *et al*., 2015; Van Leeuwen *et al*., 2015), only little is known about the economics of SLM. Filling this knowledge gap is important, as actual and perceived costs and benefits of SLM practices play a crucial role in their adoption and spreading (Douglas, 1994; Amsalu & de Graaff, 2007; Schwilch *et al*., 2014). This paper aims to contribute to a better understanding of the economics of SLM by determining what kind of economic costs and benefits accrue to local stakeholders, and by assessing how investment and maintenance costs compare to economic benefits. To this end, we analyse case study data on costs and perceived cost/benefit ratios of SLM practices contained in the World Overview of Conservation Approaches and Technologies (WOCAT) network's technology database (WOCAT, 2013a).

Economics provides a theoretical framework, the theory of production, allowing to analyse farmers' decisions to adopt or not adopt SLM practices. The standard model used in this theory conceptualises a farmer as a rational agent maximising her or his profit over time. Nkonya *et al.* (2011) propose to model a farmer's decision between land-degrading and land-conserving management practices as an intertemporal choice between the cost of action and the cost of inaction. On this basis, a landowner will continue to use land-degrading management practices as long as the marginal costs of degradation are smaller than the marginal costs associated with the land conservation practice. Economic theory thus agrees with common sense that investments in SLM, whether in form of labour, capital or land, should result in tangible benefits such as greater production, avoidance of production losses and labour or other cost savings in order to be of interest to land users (Winpenny, 1996).

A vast interdisciplinary literature empirically investigates the reasons for adoption or non-adoption of SLM practices (for an extensive literature review, see e.g. Pannell *et al*., 2011).

*Correspondence to: M. Giger, Centre for Development and Environment, University of Bern, Bern, Switzerland.
E-mail: markus.giger@cde.unibe.ch

Inwhat follows, we focus on selected empirical contributions. Several early studies (Ruthenberg, 1980; Ellis, 1993) showed that, in line with theoretical expectations, smallholders indeed follow an economic logic. De Graaff *et al*. (2008) confirmed these results by demonstrating that profitability has a positive and significant influence on continued use of an already adopted technology. Extensive research on rural livelihoods (Chambers & Conway, 1992; Wiesmann, 1998; Rist, 2000; Schneider *et al*., 2010) revealed additional nuances, showing that factors such as social relations and cultural norms also play an important role in farmers' decisions. Other household characteristics have found to be important as well, although researchers have been unable to single out any uniform influence of factors such as age, education or farm size (Nkonya *et al*., 2011). Clearly, farmers' decisions and preferences are influenced by a much wider range of socio-economic and cultural factors than just the monetary costs and benefits of establishing and maintaining SLM practices. This further adds to the complexity of assessing the reasons for adoption of SLM practices, as non-monetary costs and benefits are perceived differently by different actors (Schwilch *et al*., 2014). Understanding farmers' perceptions of land degradation and SLM practices has thus become a key focus of a growing strand of the empirical literature on SLM adoption. In an early seminal paper, Cary & Wilkinson (1997) identify perceived profitability of SLM practices as the most important factor explaining adoption of conservation measures by farmers. The importance of whether farmers perceive a given practice as profitable has since been confirmed by several other studies (Knowler, 2004; Amsalu & de Graaff, 2007; D'Emden *et al*., 2008; de Graaff *et al*., 2008). Moreover, research has shown that land users' perception of land degradation as being a problem is an additional important factor explaining adoption (Norris & Batie, 1987; Pender & Kerr, 1998; Shiferaw & Holden, 1998; Baidu-Forson, 1999; Sidibé, 2005; Doss, 2006; Amsalu & de Graaff, 2007; de Graaff *et al*., 2008; Nkonya *et al*., 2011; Tesfaye *et al*., 2014).

Despite the importance of actual and perceived costs and benefits of SLM for its adoption, relatively little detailed knowledge is available about them. The few existing studies present a nuanced picture. Nkonya *et al*. (2011) compiled results from 11 studies that applied cost/benefit analysis to assess the profitability of SLM practices in different regions of the world between 1989 and 2009. They found that profitability depended on the study region, the type of SLM practice, crops, the discount rate applied and the intensity of an SLM practice (e.g. hedgerow intensity). About half of the practices these studies investigated were profitable (authors' calculation based on Nkonya *et al*., 2011). Byiringiro & Reardon (1996) found in Rwanda that investment in SLM could increase the marginal value product of land by 21%. Kaliba & Rabele (2004) analysed output data of 50 smallholder farmers in Lesotho and concluded that soil conservation increased yields by 17–27%, which is more than what could have been gained by applying additional inorganic fertilisers alone. Adegbidi *et al*. (2004) found large observable productivity effects of indigenous SLM investments (increases of 50–70%) in Benin, but only for fairly large plots. Kassie *et al*. (2008) showed in Ethiopia that stone bunds enhanced productivity only in drier areas and stressed the need for site-specific technologies. Mekonnen *et al*. (2015) found that sediment storage dams efficiently prevented soil losses in Ethiopia but involve high costs and are thus not affordable for small-scale farmers. Herweg & Ludi (1999) concluded, based on research in Ethiopia and Eritrea, that SLM is rarely profitable for farmers in the short term. Bravo-Ureta *et al*. (2006) found positive impacts of soil conservation practices on farm income based on an econometric analysis of farm household surveys in Honduras and El Salvador. Giger *et al*. (1999), in an early review of a sample of 50 case studies by the WOCAT network, found that only about half of the cases for which sufficient data were available showed a positive cost/benefit ratio at the farm level when a discount factor was applied. This is in line with the findings of Nkonya *et al*. (2011), who concluded that many studies found positive effects of SLM, but that benefits depended on a range of factors such as slope, rainfall conditions and type of SLM practice.

In short, while data on private monetary costs and benefits of an SLM practice provide a basis for assessing whether farmers will be able to cover the costs of adopting the practice from their own means or whether they will need external support, understanding land users' *perceptions* of the practice's costs and benefits is just as crucial. It is thus highly interesting to analyse available data on existing SLM practices in terms of whether indeed land users perceive these practices as profitable. Using data from the WOCAT technology database (WOCAT, 2013a), this paper contributes to the literature in two ways: by analysing data on observed establishment and maintenance costs and by analysing data on perceived cost/benefit ratios of SLM practices. Our analysis offers quantitative insights on two key factors influencing farmers' decisions to adopt or not adopt SLM practices.

MATERIAL AND METHODS

Economic information about SLM practices is difficult to collect and to quantify. An accurate cost assessment is challenging, as written farm accounts are often missing, family labour and other in-kind inputs are hard to value and the exact size of the area on which the practice is applied is not always clear. An accurate benefits assessment is even more demanding. This is because knowledge about biophysical outcomes (e.g. reduced erosion levels and nutrient losses, increased water retention and carbon sequestration) as well as productivity gains and other socio-economic benefits is often incomplete. It is also challenging to value increased subsistence production or determine comparable market or farm gate prices for crops that are sold. In practice, technicians and experts are often unable to provide reliable data on these aspects, as they lack the resources, time and expertise needed for in-depth research. Moreover, costs and benefits –

particularly of well-known technologies – vary significantly depending on the economic, social and biophysical context. Despite these difficulties, the WOCAT technology database (WOCAT, 2013a) contains some basic quantitative information about observed establishment and maintenance costs, complemented with records on stakeholders' perceptions of cost/benefit ratios.

Our dataset consists of 363 case studies taken from the WOCAT technology database (WOCAT, 2013a). These case studies have been documented using the standardised WOCAT questionnaires on SLM technologies and approaches (Liniger *et al*., 2008a,b). The supporting files – Table SI and the Data S1 KMZ file in the Supporting Information – list all case studies and show their locations. The lion's share of cases are located in Africa (46% or 167 cases) and Asia (41%, 149 cases), while Europe, Latin America and Australia make up a relatively small share (27, 17 and 3 cases). A comparatively large amount of data comes from the subregions of Central Asia and East Africa, followed by West Africa and South Asia. It is important to note that the geographical distribution of the case studies is not a measure of the global spread of SLM technologies but merely reflects the strength of the WOCAT network in the different regions. The SLM technologies contained in the sample have been implemented mainly in cropland (61%), followed by grazing land (15%), mixed land use systems (14%) and forest/woodland (4%). Reporting of case studies seems to be biased towards cropland, even though land degradation is often also severe in land devoted to other uses (e.g. grazing land). Table I provides an overview of the sample by land use and geographical region.

Two quantitative variables are used to analyse costs: establishment costs and maintenance costs. *Establishment costs* are defined as the specific one-off initial costs that are incurred when adopting an SLM technology. They are covered by investments over a period that can last anything from a few weeks to 2 or 3 years. Establishment costs typically include extra labour, purchase or hire of machinery and equipment and purchase of seedlings. Establishment cost data are expressed in current US dollars per hectare. We accounted for inflation by transforming establishment cost data into constant 2010 US dollars per hectare. *Maintenance costs* refer to costs incurred on a regular basis to keep the established system functional. They generally consist of labour and the costs of equipment and agricultural inputs. Maintenance cost data are expressed in current US dollars per hectare and year. To account for inflation, we transformed the data into constant 2010 US dollars per hectare and year. To assess *perceived cost/benefit ratios* of SLM technologies, we rely on four qualitative variables taken from the WOCAT (2013a) database: perceived short-term ratio of overall benefits to establishment costs, perceived long-term ratio of overall benefits to establishment costs, perceived short-term ratio of overall benefits to maintenance costs and perceived long-term ratio of overall benefits to maintenance costs. Short-term is defined as a period of 3 years, whereas long-term is defined as a period of 10 years. Each variable is a discrete index ranging from 1 to 7, where 1 equals *very negative* and 7 equals *very positive*. Perceived cost/benefit ratios of SLM technologies were documented by the WOCAT network based on information and assessments from all stakeholders involved in their implementation, including land users, agricultural advisors and project staff. Lastly, we exploit an additional qualitative variable on land users' motivations for adopting a practice. The data on land users' motivations are taken from a second WOCAT (2013b) database on SLM approaches. According to WOCAT, an SLM approach consists of 'the ways and means of support that help introduce, implement, adapt, and apply SLM technologies on the ground' (Liniger & Critchley, 2007; Schwilch *et al*., 2012).

We provide a detailed descriptive analysis of investment and maintenance costs per hectare of land conserved, taking into account differences between land use systems, geographical regions and the area of land used by households (referred to as 'land size' in the succeeding text). Moreover, we present and analyse data on perceived relationships between benefits and costs, on the nature of benefits and on land users' motivations for adopting SLM practices. According to investment theory, benefits and costs that accrue in the future have to be discounted. This means that future benefits and costs must be given less weight in the calculation than short-term costs and benefits (Gittinger, 1982; Clark, 1996; TEEB, 2010; Nkonya *et al*., 2011; Requier-Desjardins *et al*., 2011). The level of the discount rate chosen heavily influences the results of the calculation. The rationale for applying a discount rate and its applicability to environmental and other long-term issues has been widely discussed (Clark, 1996; Winpenny, 1996; TEEB, 2010; Adhikari & Nadella, 2011; Nkonya *et al*., 2011; Requier-Desjardins *et al*., 2011). We refrained from applying a discount rate in this study, as the required quantitative

Table I. Dominant land uses by region

Continent	Cropland	Grazing land	Forest/woodland	Mixed land[a]	Other land	Total
Australia	2	1	0	0	0	3
Asia	87	26	8	19	9	149
Europe	22	2	1	2	0	27
America	10	1	0	2	4	17
Africa	100	23	6	28	10	167
Total	221	53	15	51	23	363

[a]Mixed land refers to a combination of land use types as dominant land use (e.g. agroforestry).

data were unavailable in many cases. But, by relating *perceived* benefits to costs, our valuation approach nonetheless takes account of the fact that future benefits are less certain to accrue and often less valuable to farmers than short-term benefits.

RESULTS

We use three distinct categorisation systems for our descriptive analyses. First, we analyse costs and perceived cost/benefit ratios by type of SLM measure. We rely on the categorisation proposed in the WOCAT questionnaire on SLM technologies, distinguishing four basic types of measures. For an overview, refer to the top panel in Table II. *Structural measures* are found to be the most frequent type in the sample (34%) and include terraces (bench and forward/backward sloping), bunds and banks (level and graded), dams, pans, ditches (level and graded), walls, barriers and palisades. *Agronomic measures* are also fairly frequent (18%) and include improvement of soil cover (e.g. green cover and mulch), enhancement of organic matter and soil fertility (e.g. manuring), soil surface treatments (e.g. conservation tillage) and subsurface treatments (e.g. deep ripping). *Vegetative measures* account for 12% of cases and include plantation and reseeding of tree and shrub species (e.g. live fences and tree crows), grasses and perennial herbaceous plants (e.g. grass strips). *Management measures* make up 11% of cases and include change of land use type (e.g. area enclosure), change of management/intensity level (e.g. from grazing to cut-and-carry), major changes in timing of activities and control or change of species composition. Combinations of vegetative with structural and vegetative with management measures occurred frequently (8% and 4%) and were therefore considered as individual categories in our analysis. All other combinations, including combinations of three or all types of measures, were pooled in a residual 'other combinations' category (14%).

Second, we analyse costs and perceived cost/benefit ratios according to the type of SLM intervention, which depends on the stage of degradation of the land on which the intervention occurs. Again, we adopt the classification used in the WOCAT questionnaire. It distinguishes three different types of interventions (Liniger & Critchley, 2007; Schwilch *et al*., 2012): *prevention* refers to SLM practices that maintain natural resources and their environmental and productive functions on land that might be at risk of degradation. It implies that good land management practices are already in place. *Mitigation* refers to interventions on land where degradation has already begun. The aim is to halt further degradation and start improving resources and their ecosystem functions. Mitigation impacts tend to be noticeable in the short to medium term and provide a strong incentive for further efforts. *Rehabilitation* is required when the land is already degraded to the extent that it has become practically unproductive, its previous use is no longer possible and the ecosystem is seriously disturbed. Rehabilitation usually involves high investment costs, while benefits accrue in the medium to long term. The middle panel of Table II

Table II. Categorisation of case studies according to types of SLM measures, types of interventions and land size

	Categories	No. of case studies	Percentage of total sample[b] (%)
Types of SLM measures[a]	Agronomic	61	18
	Structural	114	34
	Vegetative/structural	27	8
	Vegetative	40	12
	Vegetative/management	13	4
	Management	36	11
	Other combination	49	14
	Total [c]	340	100
Types of interventions[a]	Prevention and rehabilitation	6	2
	Prevention only	73	24
	Prevention and mitigation	21	7
	Mitigation only	110	37
	Mitigation and rehabilitation	11	4
	Rehabilitation only	73	24
	Prevention/rehabilitation/mitigation	6	2
	Total [c]	300	100
Land size[a]	0·5–1 ha	90	38
	1–2 ha	54	23
	2–5 ha	37	16
	5–15 ha	14	6
	15–50 ha	15	6
	50–500 ha	17	7
	500–10 000 ha	10	4
	Total [c]	237	100

SLM, sustainable land management.
[a]Only first ranks are reported.
[b]Percentages might not add up due to rounding.
[c]Case studies where category values were missing have been omitted.

indicates that roughly 70% of the cases focus on prevention and/or mitigation while 30% of the cases involve rehabilitation measures.

Finally, costs and perceived cost/benefit ratios are analysed according to land size, in hectares (i.e. total cropland area per household, total grazing area per household and total forestland per household). The bottom panel of Table II reveals that 77% of the technologies have been implemented by households with small land areas (0·5–5 ha), 12% by households with medium-sized land areas (5–50 ha) and 11% by households with large to very large land areas (50–10 000 ha).

Analysing Observed Costs of SLM Technologies

Observed costs in constant 2010 US dollars by type of measure are analysed in Figure 1a. The 258 technologies for which these data were available had median establishment costs of \$500/ha. Values ranged from less than 20 to over \$5000/ha, with half of all cases between 193 and \$1918/ha (interquartile range). The median maintenance costs of the same technologies amounted to \$100/ha y^{-1}, with half of the practices costing between 27 and \$324/ha y^{-1} (interquartile range). There is thus a huge variation in the costs of both establishment and maintenance. This is due to the great diversity of SLM measures. Some of the high-cost technologies involve structural

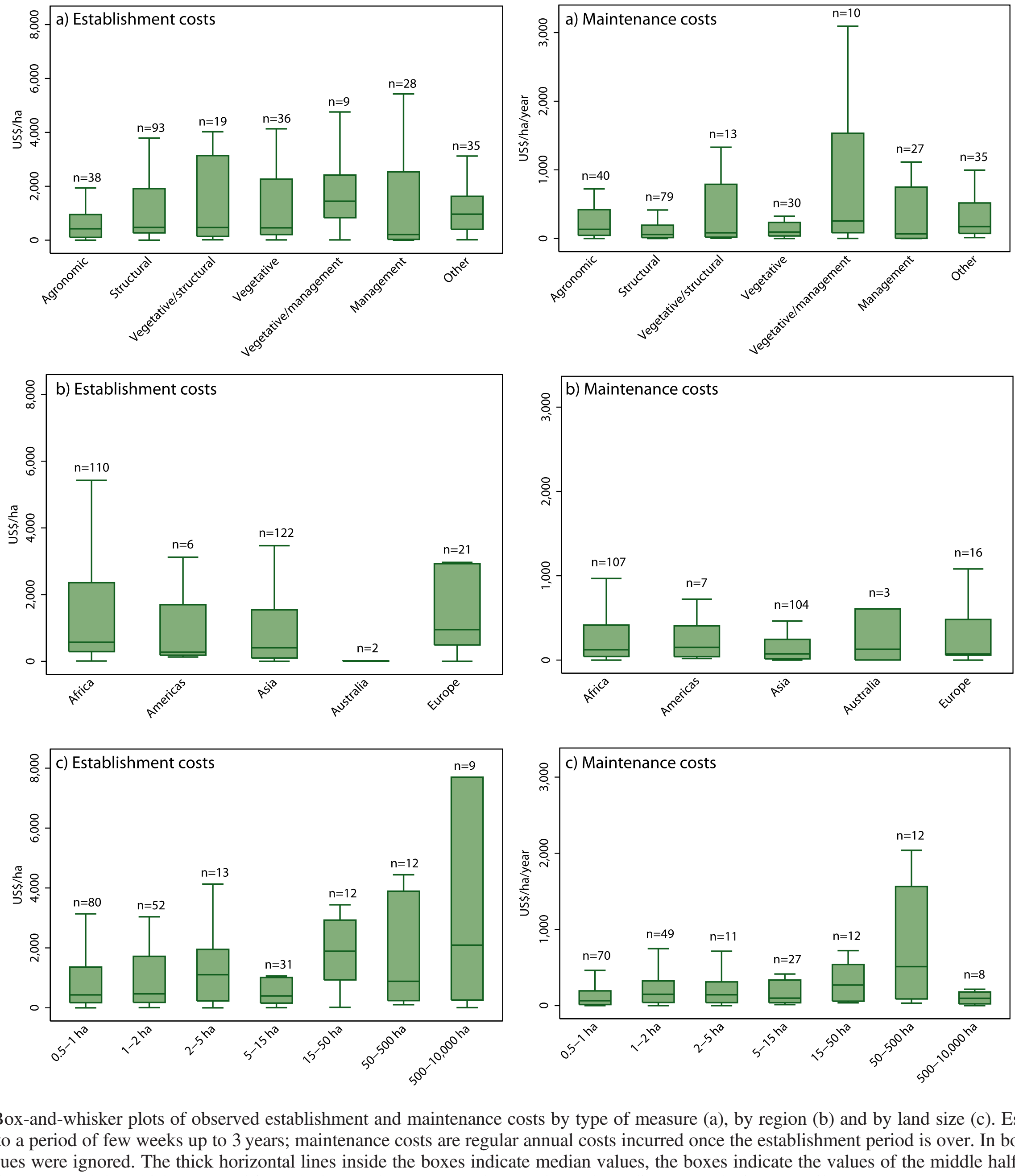

Figure 1. Box-and-whisker plots of observed establishment and maintenance costs by type of measure (a), by region (b) and by land size (c). Establishment costs refer to a period of few weeks up to 3 years; maintenance costs are regular annual costs incurred once the establishment period is over. In both columns, missing values were ignored. The thick horizontal lines inside the boxes indicate median values, the boxes indicate the values of the middle half of all cases (interquartile range) and the whiskers extend from the box to the extreme values. Values whose distance to the interquartile range was greater than 1·5 times the interquartile range (length of box) were considered outliers. [Colour figure can be viewed at wileyonlinelibrary.com]

measures to control water flow (e.g. dams or runoff channels) or to manage erosion (e.g. terraces). The highest median establishment costs as well as median maintenance costs were reported for technologies involving combined vegetative/management measures – a small category (ten cases) that includes high-cost afforestation projects in Central Asia and West Africa, which were only possible thanks to support from development agencies. In 43% of cases, the establishment costs were fully covered by the farmers themselves. The median establishment costs of these technologies were \$350/ha, with half of the cases ranging between 130 and \$1080/ha. The median maintenance costs were \$80/ha, with half of the cases ranging between \$20 and \$220 per hectare. Overall, these technologies cost slightly less than those that were partly supported from outside.

Regional differences in observed median establishment and maintenance costs in constant 2010 US dollars (Figure 1b) were relatively small. Median establishment costs were higher in Europe than in Asia and Africa; this difference was to be expected and is probably mainly due to higher labour costs. The samples from the Americas and Australia are almost too small for a meaningful comparison; for example, the very low establishment costs found in Australia are owed to the fact that the sample includes no more than three technologies, two consisting of conservation agriculture and one of grazing management, and all requiring no initial investments. It is worth noting that although establishment costs differ considerably between Africa, the Americas and Asia, the median values were rather moderate at \$572, \$276 and \$405/ha, respectively. But, even this level of costs may be very high for local land users to cover from their own means. Median maintenance costs differ less between continents than establishment costs, ranging from \$72/ha y^{-1} for Europe to \$151/ha y^{-1} for the Americas. Again, variation within each region is high due to the great diversity of technologies.

Differences in median establishment costs by land size category are substantial (Figure 1c), ranging from \$398/ha for land sizes between 5 and 15 ha to \$2092/ha for land sizes between 500 and 10 000 ha. This suggests a positive correlation between land size and establishment costs. However, it is worth noting that the size of our sample diminished considerably due to missing information about land size, and that the largest land size category (500–10 000 ha) contains relatively few cases, making the median sensitive to individual values. This category contains a number of relatively cost-intensive projects (afforestation, pilot project for bush clearing, physical conservation structures and others) that were implemented with external support. The variation in median maintenance costs is slightly smaller but still considerable. The second-largest land size category (50–500 ha) was found to have the highest median maintenance costs (examples include conservation tillage for large-scale cereal production, improvement of a livestock grazing scheme, use of mineralised artesian water to organise irrigated crop farming and others), while the largest land size category (500–10 000 ha) has rather low median maintenance costs, comparable to those of the smaller land size categories. A complementary simple pairwise correlation analysis between land size and establishment (maintenance) costs corroborates the evidence of a positive correlation between land size and costs, as it produces a positive correlation coefficient of 0·16 (0·21) with an associated p-value of 0·021 (0·003).

Analysing Perceived Cost/Benefit Ratios

Results of our analysis of perceived short-term and long-term cost/benefit ratios are displayed in Tables III–V. Overall, we found that the cost/benefit ratio was perceived to be positive in a majority of cases, although not all. Out of the 308 technologies in our sample for which the information was available (see upper panel of Table III), almost three quarters (73%) were perceived as having a positive (61%) or at least a neutral (12%) ratio of benefits to establishment costs in the short term. This implies that SLM measures are considered to pay off after as little as 1–3 years. In the remaining quarter of the cases, the ratio was assessed as slightly negative (11%) to negative or very negative (16%). The perceived ratio of long-term benefits to establishment costs is positive or very positive for 97% of cases. Only 1% of all cases were perceived as having a very negative to slightly negative ratio of long-term benefits to costs. A similar picture emerges when looking at perceived ratios of benefits to maintenance costs (see lower panel of Table III). Out of the 316 case studies for which data were available, 91% of technologies were found to have benefits that outweighed or at least equalled maintenance costs in the short term, whereas the ratio was slightly negative to very negative in around 9% of cases. Again, the picture becomes even more positive when looking at the long term: a staggering 96% of cases show a slightly positive to very positive ratio of long-term benefits to maintenance costs, and less than 2% have a slightly negative to very negative ratio.

Table III displays perceived cost/benefit ratios by type of measure. We found that management measures have the best perceived ratio of short-term benefits to establishment as well as to maintenance costs. This can be explained by the fact that many management measures mainly consist in a change of practice and require almost no investments; accordingly, their benefits quickly outweigh the costs. Vegetative measures have the worst perceived short-term cost/benefit ratio with respect to both establishment costs and maintenance costs: in 43% (22%) of the cases, we observed a very negative to slightly negative ratio with respect to establishment (maintenance) costs. This might be due to high costs of replacing plants and seeds and high costs of keeping plants healthy and productive and to the fact that vegetative measures such as plantation or reseeding of tree and shrub species take time to develop their effects. The latter hypothesis seems rather credible, as the perceived long-term cost/benefit ratio for vegetative measures is highly positive and comparable to that of other types of measures; vegetative measures thus seem to catch up over time in terms of their cost/benefit ratio. Long-term cost/benefit

Table III. Perceived short-term[a] and long-term[b] benefits of sustainable land management measures in relation to establishment and maintenance costs, by type of measure

	Very negative to negative		Slightly negative		Neutral		Slightly positive		Positive to very positive	
	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term
In relation to establishment costs (%)										
Agronomic ($n=53$; $n=47$)	13	0	9	0	13	2	13	9	51	89
Structural ($n=106$; $n=107$)	15	1	11	1	12	3	21	5	41	91
Vegetative/structural ($n=26$; $n=25$)	23	0	8	0	23	4	12	0	35	96
Vegetative ($n=35$; $n=37$)	17	0	26	0	20	0	11	5	26	95
Vegetative/management ($n=11$; $n=9$)	18	0	9	0	0	0	27	0	45	100
Management ($n=32$; $n=31$)	3	3	6	0	6	0	22	3	63	94
Other combination ($n=45$; $n=45$)	22	0	7	0	7	0	24	2	40	98
Total[c] ($n=308$; $n=301$)	16	1	11	0	12	2	19	4	42	93
In relation to maintenance costs (%)										
Agronomic ($n=59$; $n=54$)	2	0	5	0	7	2	19	11	68	87
Structural ($n=105$; $n=105$)	3	1	4	0	13	6	19	8	61	86
Vegetative/structural ($n=25$; $n=26$)	4	0	0	0	24	0	4	4	68	96
Vegetative ($n=36$; $n=38$)	8	0	14	0	31	0	14	13	33	87
Vegetative/management ($n=12$; $n=10$)	8	0	17	0	8	0	25	0	42	100
Management ($n=32$; $n=31$)	3	3	3	3	6	3	13	0	75	90
Other combination ($n=47$; $n=46$)	9	0	4	2	9	0	9	2	70	96
Total[d] ($n=316$; $n=310$)	4	1	5	1	13	3	15	7	62	89

Percentages might not add up due to rounding.
[a]'Short-term' refers to a period of 1–3 years.
[b]'Long-term' refers to a period of 10 years.
[c]Short-term: 55 case studies omitted due to missing values; long-term: 62 case studies omitted due to missing values.
[d]Short-term: 47 case studies omitted due to missing values; long-term: 53 case studies omitted due to missing values.

Table IV. Perceived short-term[a] and long-term[b] benefits of sustainable land management measures in relation to establishment and maintenance costs, by type of intervention

	Very negative to negative		Slightly negative		Neutral		Slightly positive		Positive to very positive	
	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term
In relation to establishment costs (%)										
Prevention only ($n=65$; $n=65$)	15	0	14	2	14	3	17	2	40	94
Prevention/rehabilitation ($n=5$; $n=6$)	0	0	0	0	40	0	20	17	40	83
Rehabilitation only ($n=68$; $n=66$)	19	2	13	0	10	0	18	0	40	98
Mitigation/rehabilitation ($n=11$; $n=10$)	0	0	27	0	9	0	27	10	36	90
Mitigation only ($n=99$; $n=100$)	14	1	8	0	15	1	18	7	44	91
Prevention/mitigation ($n=18$; $n=15$)	28	0	6	0	11	20	6	13	50	67
All ($n=6$; $n=4$)	17	0	0	0	0	0	33	0	50	100
Total[c] ($n=272$; $n=266$)	16	1	11	0	13	2	18	5	42	92
In relation to maintenance costs (%)										
Prevention only ($n=67$; $n=65$)	1	0	4	0	16	5	13	6	64	89
Prevention/rehabilitation ($n=5$; $n=6$)	0	0	0	0	20	0	20	17	60	83
Rehabilitation only ($n=69$; $n=66$)	6	2	7	2	19	0	13	5	55	92
Mitigation/rehabilitation ($n=10$; $n=9$)	10	0	10	11	0	0	30	22	50	67
Mitigation only ($n=103$; $n=105$)	6	1	6	0	10	2	17	6	62	91
Prevention/mitigation ($n=20$; $n=19$)	0	0	10	0	20	5	5	21	65	74
All ($n=6$; $n=4$)	33	0	0	0	17	0	0	0	50	100
Total[d] ($n=280$; $n=274$)	5	1	6	1	14	2	14	7	60	89

Percentages might not add up due to rounding.
[a]'Short-term' refers to a period of 1–3 years.
[b]'Long-term' refers to a period of 10 years.
[c]Short-term: 91 case studies omitted due to missing values; long-term: 97 case studies omitted due to missing values.
[d]Short-term: 83 case studies omitted due to missing values; long-term: 89 case studies omitted due to missing values.

Table V. Perceived short-term[a] and long-term[b] benefits of sustainable land management measures in relation to establishment and maintenance costs, by land size

	Very negative to negative		Slightly negative		Neutral		Slightly positive		Positive to very positive	
	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term
In relation to establishment costs (%)										
0·5–1 ha ($n = 81$; $n = 82$)	15	1	9	0	15	0	16	6	46	93
1–2 ha ($n = 51$; $n = 52$)	10	0	14	0	12	2	20	4	45	94
2–5 ha ($n = 34$; $n = 34$)	18	0	21	0	9	3	24	3	29	94
5–15 ha ($n = 13$; $n = 13$)	31	0	0	0	15	0	15	0	38	100
15–50 ha ($n = 15$; $n = 14$)	33	0	0	0	0	0	7	7	60	93
50–500 ha ($n = 15$; $n = 14$)	13	0	13	0	33	21	13	14	27	64
500–10 000 ha ($n = 10$; $n = 10$)	40	0	0	0	10	10	20	10	30	80
Total[b] ($n = 219$; $n = 220$)	17	0	10	0	13	3	17	5	42	91
In relation to maintenance costs (%)										
0·5–1 ha ($n = 84$; $n = 8$)	4	1	5	0	9	1	15	6	67	92
1–2 ha ($n = 55$; $n = 54$)	2	0	8	0	19	4	9	6	62	91
2–5 ha ($n = 32$; $n = 33$)	6	0	9	3	16	3	13	6	56	88
5–15 ha ($n = 13$; $n = 13$)	15	0	0	0	8	0	15	0	62	100
15–50 ha ($n = 15$; $n = 14$)	7	0	7	0	0	0	0	7	87	93
50–500 ha ($n = 16$; $n = 15$)	6	0	13	0	19	7	31	33	31	60
500–10 000 ha ($n = 10$; $n = 10$)	10	0	10	0	30	10	20	20	30	70
Total[b] ($n = 223$; $n = 225$)	5	0	7	0	13	3	14	5	61	91

Percentages might not add up due to rounding.
[a]'Short-term' refers to a period of 1–3 years.
[b]'Long-term' refers to a period of 10 years.
[c]Short-term: 144 case studies omitted due to missing values; long-term: 143 case studies omitted due to missing values
[d]Short-term: 140 case studies omitted due to missing values; long-term: 138 case studies omitted due to missing values.

ratios differ considerably less between types of measures than short-term ratios and are highly positive for all types of measures.

Table IV displays perceived cost/benefit ratios by type of intervention. Overall, the differences between types of interventions are not very marked. One result stands out, however: we found a rather elevated percentage (29%) of very negative to slightly negative short-term benefits compared with establishment costs for prevention-only measures. This result might be explained by the fact that prevention measures do not directly produce benefits but generate relatively high costs – at least if compared with the alternative of doing nothing. At first glance, this result seems to contradict previous findings stating that prevention generally has a more favourable cost/benefit ratio than mitigation and rehabilitation (Schwilch *et al.*, 2012). However, looking at the long term, a striking 98% of prevention-only measures have a positive to very positive perceived cost/benefit ratio. Our results thus simply nuance the findings of Schwilch *et al.* (2012): the cost/benefit ratios of prevention-only measures are below average in the short term but above-average in the long term. Finally, we observed that benefits regularly outweigh establishment costs, even in the short term, as long as investment costs are low. The higher the investment costs, the more likely the cost/benefit ratio is negative. This is not surprising, but it underlines once again the importance of low-cost SLM solutions.

Table V reports perceived cost/benefit ratios by land size category. Again, it is worth noting that our sample diminished considerably for this analysis due to missing land size data. Differences in short-term benefits compared with both establishment and maintenance costs are fairly marked. Generally speaking, the results indicate that the larger the land size, the higher the percentage of negative short-term cost/benefit ratios and the lower the percentage of positive short-term cost/benefit ratios. This finding, together with the results from the cost analysis (Figure 1c), suggests that technologies with rather elevated fixed costs tend to be implemented more often by land users with large areas of land. However, differences are considerably smaller when looking at the long term, and as much as 90% of cases in the largest land size category (500–10 000 ha) actually achieve a positive or very positive perceived long-term cost/benefit ratio. This suggests that the SLM technologies implemented in cases belonging to this category are highly profitable, but only after several years.

Analysing Land Users' Motivations for Adoption of SLM

In what follows, we complement the previous analysis by making use of information on land users' motivation for adopting SLM technologies. We analysed a total of 128 cases for which land users' motivations were documented. Some of the SLM technologies analysed in the previous text were implemented under the same approach, whereas others were not associated with any specific approach. Table VI displays an overview of the results.

Land users' most frequently mentioned motivations for adopting a given SLM technology are production (24%), increased profitability (20%) and well-being and livelihood improvement (20%). In addition, reduced workload was mentioned in 5% of all cases. All four answers are directly or indirectly related to economic considerations, and together, they represent a total of 69% of the mentioned motivations. This suggests that economic considerations are clearly land users' primary motivations for implementing SLM. Further motivations include environmental benefits and a number of social and cultural values, such as affiliation to a project or a group, compliance with rules and regulations or prestige and social pressure.

DISCUSSION

Overall, our results suggest that land users perceive most SLM technologies in our sample as having benefits that justify the required investments. Given that we show – in line with previous research – that economic reasons are key determinants in land users' decisions to adopt SLM technologies, these technologies can be considered well suited for being scaled up and replicated elsewhere.

However, several important points deserve special attention. First, we should recall that our sample of SLM practices was drawn from the WOCAT database, which focuses on 'promising and good' practices. Our results are therefore

Table VI. Main motivations of land users for implementing sustainable land management

Main motivation[a]	No. of case studies	Percentage of total sample [c] (%)
Affiliation to movement/project/group/networks	9	7
Prestige and social pressure	3	2
Environmental consciousness, morals and health	12	9
Well-being and livelihood improvement	25	20
Reduced workload	6	5
Production	31	24
Rules and regulations (fines) and enforcement	5	4
Increased profit (ability) and improved cost/benefit ratio	26	20
Payments/subsidies	11	9
Total[b]	91	100

[a]Only first ranks are reported.
[b]235 case studies have been omitted due to missing values.
[c]Percentages might not add up due to rounding.

biased towards successful practices and do not represent land management practices in general. As all technologies in our study were assessed as good or promising SLM practices, they could all be expected to have a reasonable cost/benefit ratio.

Second, even though our analyses include only best-practice technologies, the findings show that roughly 25% of the case studies in our sample are perceived as having negative returns on investment throughout the first 1–3 years. Moreover, the percentage of negative short-term cost/benefit ratios increases with the area of land used by households. Thus, even though a technology may be perceived as highly profitable in the long run, the initial investment period can constitute an important barrier to adoption and might prevent it from spreading and being scaled up. This raises questions: why and how have land users been able to afford these investments? One explanation is that land users often implement such systems incrementally, gradually enlarging the area under SLM every year, or building terraces in a continuous effort over many years or even generations. A second partial explanation concerns external support, even though such support does not appear to be the main motivation of land users for adopting a practice (see Section on Analysing Land Users' Motivations for Adoption of SLM). In 57% of the cases studied, investments were supported from outside, for example by development projects or government programmes. Such support is likely to be justified by significant off-site benefits, although this was not investigated in detail in the present paper. Nevertheless, in as many as 43% of cases studied, the establishment costs were fully covered by land users – a finding that is worth emphasising. Our results thus imply that land users need to have a long-term planning horizon. This requires stable economic and social conditions and secure tenure rights, among other things (Liniger *et al*., 2007). Additional external investment support can improve the chances for rapid uptake and replication – but only if potential negative side-effects of such subsidies are minimised. Practice has shown that this is no easy task (Giger, 1999; Hellin & Schrader, 2003).

Third, while our results show that land users implement SLM technologies because they are convinced of the benefits these technologies have, land users are nonetheless frequently unable to express even economic benefits in monetary terms. Moreover, the benefits that land users perceive are not always economic but may also include other dimensions such as environmental considerations and compliance with social and cultural norms. As a next step, it would thus be interesting to analyse the wide variety of perceived benefits in greater detail, for instance using WOCAT's detailed data on perceived benefits. This additional analysis could also shed light on SLM-induced productivity gains. The latter are important as SLM intends to contribute to a profitable economic development, which requires improvements in productivity.

Several methodological caveats limit the scope of the present paper. First, the dataset used is not a randomised sample of successful SLM practices but was compiled based on opportunities arising within the WOCAT network and among its partners. Second, the shortage of additional economic data about on-site and off-site benefits of the technologies studied is an important drawback. This limitation can be explained by the persistent difficulties faced by both experts and land users in quantifying the benefits of SLM technologies. A comprehensive and in-depth investigation of costs and benefits of SLM will thus require a detailed review of the WOCAT case studies and additional research to fill information gaps. Third, many of the respondents in the case studies were directly involved in projects implementing SLM technologies. Such respondents were highly familiar with the technologies in question, which can lead to a certain bias too. Lastly, while the questionnaires were field-tested and revised a number of times and are now relatively easy to understand and use, we cannot exclude diverging interpretation of questions and thus subjective bias in the data (for a discussion, see Schwilch *et al*., 2014).

CONCLUSIONS

We exploited the WOCAT technology database and analysed observed costs and perceived cost/benefit ratios of existing SLM technologies. We find that land users perceive a large majority of the technologies in the database as having a positive long-term cost/benefit ratio. About three quarters of these technologies even have a positive or at least a neutral perceived short-term cost/benefit ratio. Moreover, our results give a good quantitative indication of the range of investment and maintenance costs that arise from SLM practices documented in the WOCAT database: many of the practices cause low to moderate costs, but the level varies considerably due to the great diversity of measures and of contexts in which they are implemented. The costs of the technologies that land users implemented without external support were slightly below average but still substantial from the point of view of land users. In order to make such investments, land users need stable economic conditions and secure tenure rights, as adoption is often a gradual process that lasts many years.

ACKNOWLEDGEMENTS

WOCAT would like to thank all contributing SLM specialists and all of its donors, especially the Swiss Agency for Development and Cooperation (SDC), the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), the International Fund for Agricultural Development (IFAD), the European Union and all WOCAT partners. The authors would also like to thank Dario Stocker for data analysis and Marlène Thibault for editing the manuscript.

REFERENCES

Adegbidi A, Gandonou E, Oostendorp R. 2004. Measuring the productivity from indigenous soil and water conservation technologies with household fixed effects: a case study of hilly mountainous areas of Benin. *Economic Development and Cultural Change* **52**: 313–346. DOI:10.1086/381018.

Adhikari B, Nadella K. 2011. Ecological economics of soil erosion: a review of the current state of knowledge. *Annals of the New York Academy of Sciences* **1219**: 134–152. DOI:10.1111/j.1749-6632.2010.05910.x.

Amsalu A, de Graaf J. 2007. Determinants of adoption and continued use of stone terraces for soil and water conservation in an Ethiopian highland. *Ecological Economics* **61**: 294–302. DOI:10.1016/j.ecolecon.2006.01.014.

Angassa A. 2014. Effects of grazing intensity and bush encroachment on herbaceous species and rangeland condition in southern Ethiopia. *Land Degradation & Development* **25**: 438–451. DOI:10.1002/ldr.2160.

Baidu-Forson J. 1999. Factors influencing adoption of land-enhancing technology in the Sahel: lessons from a case study in Niger. *Agricultural Economics* **20**: 231–239. DOI:10.1016/S0169-5150(99)00009-2.

Batjes NH. 2014. Projected changes in soil organic carbon stocks upon adoption of recommended soil and water conservation practices in the Upper Tana River catchment, Kenya. *Land Degradation & Development* **25**: 278–287. DOI:10.1002/ldr.2141.

Bravo-Ureta BE, Solis D, Cocchi H, Quiroga RE. 2006. The impact of soil conservation and output diversification on farm income in Central American hillside farming. *Agricultural Economics* **35**: 267–276. DOI:10.1111/j.1574-0862.2006.00161.x.

Berendse F, van Ruijven J, Jongejans E, Keesstra SD. 2015. Loss of plant species diversity reduces soil erosion resistance of embankments that are crucial for the safety of human societies in low-lying areas. *Ecosystems* **18**: 881–888. DOI:10.1007/s10021-015-9869-6.

Brevik EC, Cerdà A, Mataix-Solera J, Pereg L, Quinton JN, Six J, Van Oost K. 2015. The interdisciplinary nature of SOIL. *SOIL* **1**: 117–129. DOI:10.5194/soil-1-117-2015.

Byiringiro F, Reardon T. 1996. Farm productivity in Rwanda: effects of farm size, erosion, and soil conservation investments. *Agricultural Economics* **15**: 127–136. DOI:10.1016/S0169-5150(96)01201-7.

Cary JW, Wilkinson RL. 1997. Perceived profitability and farmers' conservation behaviour. *Journal of Agricultural Economics* **48**: 13–21. DOI:10.1111/j.1477-9552.1997.tb01127.x.

Chambers R, Conway GR. 1992. *Sustainable rural livelihoods: practical concepts for the 21st century*, IDS discussion paper no. 296. Institute of Development Studies (IDS): Brighton, UK.

Clark R. 1996. *Methodologies for the economic analysis of soil erosion and conservation*, Working paper GEC no. 96–13. Centre for Social and Economic Research on the Global Environment: Norwich, UK.

D'Emden FH, Llewellyn RS, Burton MP. 2008. Factors influencing adoption of conservation tillage in Australian cropping regions. *Australian Journal of Agricultural and Resource Economics* **52**: 169–182.

De Graaff J, Amsalu A, Bodnar F, Kessler A, Posthumus H, Tenge A. 2008. Factors influencing adoption and continued use of long-term soil and water conservation measures in five developing countries. *Applied Geography* **28**: 271–280. DOI:10.1016/j.apgeog.2008.05.001.

Doss CR. 2006. Analyzing technology adoption using microstudies: limitations, challenges, and opportunities for improvement. *Agricultural Economics* **34**: 207–219. DOI:10.1111/j.1574-0864.2006.00119.x.

Douglas M. 1994. *Sustainable use of agricultural soils: a review of prerequisites for success or failure*, Development and environment reports, no. 11. Group for Development and Environment: Bern, Switzerland.

Ellis F. 1993. *Peasant economics: farm households and agrarian development*, 2nd edn. Cambridge, UK: Cambridge University Press.

Giger M. 1999. *Avoiding the shortcut: moving beyond the use of direct incentives. Centre for Development and Environment*. University of Bern: Bern, Switzerland.

Giger M, Liniger H, Critchley W. 1999. Use of incentives and profitability of soil and water conservation: economic analysis of WOCAT data from Eastern and Southern Africa. In *Incentives in soil conservation: from theory to practice*, Sanders DW, Huszar PC, Sombatpanit S, Enters T (eds). WASWC, Oxford & IBH Publishing: Oxford, UK; 247–274.

Gittinger JP. 1982. *Economic analysis of agricultural projects*, 2nd edn. Baltimore, MD: The John Hopkins University Press.

Hellin J, Schrader K. 2003. The case against direct incentives and the search for alternative approaches to better land management in Central America. *Agriculture, Ecosystems & Environment* **99**: 61–81. DOI:10.1016/s0167-8809(03)00149-x.

Herweg K, Ludi E. 1999. The performance of selected soil and water conservation measures: case studies from Ethiopia and Eritrea. *CATENA* **36**: 99–114. DOI:10.1016/s0341-8162(99)00004-1.

Kaliba AR, Rabele T. 2004. Impact of adopting soil conservation practices on wheat yield in Lesotho. In *Managing nutrient cycles to sustain soil fertility in sub-Saharan Africa*, Bationo A (ed). African Network for Soil Biology and Fertility (AfNet)-CIAT: Nairobi, Kenya; 593–608.

Kassie M, Pender J, Yesuf M, Kohlin G, Bluffstone R, Mulugeta E. 2008. Estimating returns to soil conservation adoption in the northern Ethiopian highlands. *Agricultural Economics* **38**: 213–232. DOI:10.1111/j.1574-0862.2007.00295.x.

Keesstra SD, Geissen V, van Schaik L, Mosse K, Piiranen S. 2012. Soil as a filter for groundwater quality. *Current Opinions in Environmental Sustainability* **4**: 507–516. DOI:10.1016/j.cosust.2012.10.007.

Knowler DJ. 2004. The economics of soil productivity: local, national and global perspectives. *Land Degradation & Environment* **15**: 543–561. DOI:10.1002/ldr.635.

Laudicina VA, Novara A, Barbera V, Egli M, Badalucco L. 2015. Long-term tillage and cropping system effects on chemical and biochemical characteristics of soil organic matter in a Mediterranean semiarid environment. *Land Degradation & Development* **26**: 45–63. DOI:10.1002/ldr.2293.

Ligonja PJ, Shrestha RP. 2015. Soil erosion assessment in Kondoa eroded area in Tanzania using universal soil loss equation, geographic information systems and socioeconomic approach. *Land Degradation & Development* **26**: 367–379. DOI:10.1002/ldr.2215.

Liniger H, Critchley W. 2007. *Where the land is greener*. World Overview of Conservation Approaches and Technologies (WOCAT): Bern, Switzerland.

Liniger HP, Schwilch G, Gurtner M, Mekdaschi Studer R, Hauert C, van Lynden G, Critchley W. 2008a: *A framework for documentation and evaluation of sustainable land management: technologies basic questionnaire*. WOCAT & Centre for Development and Environment, University of Bern: Bern, Switzerland. https://www.wocat.net/en/methods/slm-technologies-approaches.html

Liniger HP, Schwilch G, Gurtner M, Mekdaschi Studer R, Hauert C, van Lynden G, Critchley W. 2008b: *A framework for documentation and evaluation of sustainable land management: approaches basic questionnaire*. WOCAT & Centre for Development and Environment, University of Bern: Bern, Switzerland. https://www.wocat.net/en/methods/slm-technologies-approaches.html

Mandal D, Sharda VN. 2013. Appraisal of soil erosion risk in the Eastern Himalayan region of India for soil conservation planning. *Land Degradation & Development* **24**: 430–437. DOI:10.1002/ldr.1139.

Mekonnen M, Keesstra SD, Stroosnijder L, Baartman JE, Maroulis J. 2015a. Soil conservation through sediment trapping: a review. *Land Degradation & Development*. DOI:10.1002/ldr.2308.

Mekonnen M, Keestra SD, Baartman JE, Ritsema CJ, Melesse AM. (2015b). Evaluating sediment storage dams: structural off-site sediment trapping measures in northwest Ethiopia. *Cuadernos de Investigacion Geografica* **41**: 7–22. DOI: 10.18172/cig.2643

Ndah HT, Schuler J, Uthes S, Zander P, Triomphe B, Mkomwa S, Corbeels M. 2015. Adoption potential for conservation agriculture in Africa: a newly developed assessment approach (QAToCA) applied in Kenya and Tanzania. *Land Degradation & Development* **26**: 133–141. DOI:10.1002/ldr.2191.

Nkonya E, Gerber N, Baumgartner P, von Braun J, De Pinto A, Graw V, Kato E, Kloos J, Walter T. 2011. *The economics of desertification, land degradation, and drought: toward an integrated global assessment*, IFPRI discussion paper no. 01086. International Food Policy Research Institute (IFPRI): Washington, DC.

Norris E, Batie S. 1987. Virginia farmers' soil conservation decisions: an application of Tobit analysis. *Southern Journal of Agricultural Economics* **19**: 88–97.

Novara A, Gristina L, Guaitoli F, Santoro A, Cerdà A. 2013. Managing soil nitrate with cover crops and buffer strips in Sicilian vineyards. *Solid Earth* **4**: 255–262. DOI:10.5194/se-4-255-2013.

Pannell DJ, Marshall GR, Barr N, Curtis A, Vanclay F, Wilkinson R. 2011. Understanding and promoting adoption of conservation practices by rural landholders. In *Changing land management, adoption of new practices by rural landholder*, Pannell D, Vanclay F (eds). CSIRO Publishing: Clayton South, Australia.

Papanastasis VP, Bautista S, Chouvardas D, Mantzanas K, Papadimitriou M, Mayor AG, Koukioumi P, Papaioannou A, Vallejo RV. 2015. Comparative assessment of goods and services provided by grazing regulation and reforestation in degraded Mediterranean rangelands. *Land Degradation & Development*. DOI:10.1002/ldr.2368.

Pender JL, Kerr JM. 1998. Determinants of farmers' indigenous soil and water conservation investments in semiarid India. *Agricultural Economics* **19**: 113–125.

Requier-Desjardins M, Adhikari B, Sperlich S. 2011. Some notes on the economic assessment of land degradation. *Land Degradation & Development* **22**: 285–298. DOI:10.1002/ldr.1056.
Rist S. 2000. Linking ethics and the market: Campesino economic strategies in the Bolivian Andes. *Mountain Research and Development* **20**: 310–315. DOI:10.1659/0276-4741(2000)020[0310:LEATM]2.0.CO;2.
Ruthenberg H. 1980. *Farming systems in the tropics*, 3rd edn. Oxford, UK: Clarendon Press.
Schneider F, Ledermann T, Fry P, Rist S. 2010. Soil conservation in Swiss agriculture: approaching abstract and symbolic meanings in farmers' life-worlds. *Land Use Policy* **27**: 332–339. DOI:10.1016/j.landusepol.2009.04.007.
Schwilch G, Hessel R, Verzandvoort S. 2012. *Desire for greener land: options for sustainable land management in drylands*. Centre for Development and Environment, University of Bern, Alterra, Wageningen UR, World Soil Information and Technical Centre for Agricultural and Rural Cooperation: Bern, Switzerland and Wageningen, The Netherlands.
Schwilch G, Liniger HP, Hurni H. 2014. Sustainable land management (SLM) practices in drylands: how do they address desertification threats? *Environmental Management* **54**: 983–1004. DOI:10.1007/s00267-013-0071-3.
Shiferaw B, Holden T. 1998. Resource degradation and adoption of land conservation technologies in the highlands of Ethiopia: a case study of Andit Tid, North Shewa. *Agricultural Economics* **18**: 233–247. DOI:10.1016/s0169-5150(98)00036-x.
Sidibé A. 2005. Farm-level adoption of soil and water conservation techniques in northern Burkina Faso. *Agricultural Water Management* **71**: 211–224. DOI:10.1016/j.agwat.2004.09.002.
Smyth AJ, Dumanski J. 1993. *FESLM: an international framework for evaluating sustainable land management*. FAO: Rome Italy.
TEEB. 2010. *The economics of ecosystems and biodiversity: ecological and economic foundations*, Kumar P (ed). Routledge: Abingdon, UK and New York, NY.
Tejada M, Benítez C. 2014. Effects of crushed maize straw residues on soil biological properties and soil restoration. *Land Degradation and Development* **25**: 501–509. DOI:10.1002/ldr.2316.
Tesfaye A, Negatu W, Brouwer R, van der Zaag P. 2014. Understanding soil conservation decisions of farmers in the Gedeb watershed, Ethiopia. *Land Degradation and Development* **25**: 71–79. DOI:10.1002/ldr.2187.
Van Leeuwen JP, Lehtinen T, Lair GJ, Bloem J, Hemerik L, Ragnarsdóttir KV, Gísladóttir G, Newton JS, de Ruiter PC. 2015. An ecosystem approach to assess soil quality in organically and conventionally managed farms in Iceland and Austria. *SOIL* **1**: 83–101. DOI:10.5194/soil-1-83-2015.
Wiesmann U. 1998. *Sustainable regional development in rural Africa: conceptual framework and case studies from Kenya*. Bern, Switzerland: Geographica Bernensia.
Winpenny J. 1996. Economic valuation of environmental impacts: the temptations of EVE. *Project Appraisal* **11**: 247–253. DOI:10.1080/02688867.1996.9727550.
WOCAT (World Overview of Conservation Approaches and Technologies). 2013a. WOCAT database: Technology. http://cdewocat.unibe.ch/wocatQT/index.php
WOCAT (World Overview of Conservation Approaches and Technologies). 2013b. WOCAT database: Approaches. http://cdewocat.unibe.ch/wocatQA/index.php
Zhang JJ, Fu M, Zeng H, Geng YH, Hassani FP. 2013. Variations in ecosystem service values and local economy in response to land use: a case study of Wu'an, China. *Land Degradation & Development* **24**: 236–249. DOI:10.1002/ldr.1120.
Zhao G, Mu X, Wen Z, Wang F, Gao P. 2013. Soil erosion, conservation, and eco-environment changes in the Loess Plateau of China. *Land Degradation & Development* **24**: 499–510. DOI:10.1002/ldr.2246.

SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article at the publisher's web-site.

