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Full Length Research Paper

Farmers' perception of the effects of soil and water conservation structures on crop production: The case of Bokole watershed, Southern Ethiopia

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Level soil bunds (LSB) and stone bunds (SB) have been widely implemented in Bokole watershed with World Food Programme (WFP) support since 2000-2001. However, the performance of structures against the target has not been studied. This study assessed farmers' opinion on the effect of soil and water conservation (SWC) structures, particularly level soil bunds and stone bunds, in improving agricultural crop production. A household survey was carried out by stratified random sampling. Twenty-seven percent of the farmers who adopted SWC structure (29 households from the upper watershed and 62 households from the lower watershed) were randomly selected and interviewed. Three group discussions were also conducted. Based on their own indicators, a high proportion of those interviewed (79.3% in the upper and 87.1% in the lower watershed) had a positive opinion about LSB and SB on their cropland, in relation to its role in improving soil fertility and crop production. Ninety-three percent of interviewed farmers in both the upper watershed and the lower watershed perceived a change in crop yield within two years after implementation of structures. There is a need for awareness creation and for monitoring the correct management of existing soil and water conservation structures, to ensure that they function as intended, and to improve their efficiency. This can reduce the problem of a 'decrease' or 'fluctuation' in crop yield.

Key words: Crop yield, non-terraced, soil bunds, stone bund, water erosion.

INTRODUCTION

Soil is a critically important resource, the efficient management of which is vital for economic growth and development for the production of food, fibre and other necessities (Troeh et al., 1980). To accommodate the increasing demand for food, either production per unit area must be intensified, or more land must be cultivated. The option of continuously cultivating the same land without appropriate and sufficient management to replenish or maintain nutrients, will likely lead to soil degradation and its consequences. FAO (1985) indicated that the effects of soil degradation, in today's complicated world, can affect nearly every aspect of survival and development.

Ethiopia, one of the developing countries in sub-Saharan Africa, depends on agriculture to satisfy the demand for food, fibre and other goods. Nevertheless, diminishing productivity, resulting from degradation of agricultural land induced by soil erosion, has been and is still a major concern (Admasu, 2005; Aklilu and Graaff, 2006a; Teshome et al., 2012). Soil erosion and consequent land degradation has been recognized as a serious problem in Ethiopia since 1973-74, subsequent to the devastating famine of the time (Bekele and Holden, 1999; Desta et al., 2005; Wagayehu and Drake, 2003; Woldeamlak and Sterk, 2003, Woldeamlak, 2006). Measure-ments from experimental plots and a micro-watershed estimated that annual soil loss from cropland is about 42 t ha^{-1} $year^{-1}$ (Wagayehu and Drake, 2003).

Tamene et al. (2006) indicated that some 50% of the highlands of Ethiopia were already significantly eroded, and that erosion was causing an annual decline in land productivity of 2.2%. A national-level study in Ethiopia, carried out in the mid-1980s, estimated that soil erosion was removing from use some 20,000-30,000 ha of cropland annually, and projected that *ca.* 10 million highland farmers would have their lands totally destroyed by the year 2010 (Woldeamlak, 2006).

For several decades, an attempt has been made to address the soil erosion problem in Ethiopia by means of different approaches and programmes to ensure the sus-tainability of agricultural production. The largest soil and water conservation (SWC) activities in the country were those implemented during the 1970s and 1980s, mainly in a food-for-work programme (Woldeamlak, 2006).

In the Ethiopian highlands, the agricultural production system cannot maintain a permanent vegetation cover throughout the year under the given ecological, economic and social circumstances (Herweg and Ludi, 1999; Ludi, 2004). Thus, soil conservation measures are a necessary part of the system for combating erosion during critical times of the year and showed certain effect (Kato et al., 2011; Adimassu et al., 2012).

Among various soil conservation interventions, traditional stone bunds (SB) and diversion ditches are common in the study area, the Bokole watershed in southern Ethiopia. In response to the challenges of climate change and soil degradation, government pro-grammes such as the ‘safety net’, and programmes of non-governmental organizations, such as the World Food Programme (WFP), have promoted agricultural produc-tion through environmental rehabilitation since 2000 (OoARD, 2009).

Considerable efforts have been made since then to improve food security by rehabilitating degraded environments and preventing further degra-dation. The construction of level stone bunds (LSB) and SB on cropland has been a major activity of the pro-gramme in the studied watershed (OoARD, 2009).

However, with the exception of simple evaluation, the effects and impacts of watershed management, particu-larly of SWC, have not been studied. Specifically, no attempt has been made to evaluate how far they have fulfilled their ultimate aim, the attainment of food security through environmental rehabilitation. Therefore, this re-search was conducted to assess farmers’ opinion on the effect of LSB and SB in improving agricultural crop production.

MATERIALS AND METHODS

The study area

Bokole watershed is situated in Southern Nations’, Nationalities’ and Peoples’ Regional State (SNNPRS) of Ethiopia, in Dawuro zone, Loma *woreda* (Figure 1), between 6°55'-7°01'30"N lat. and 37°15'E-37°19'E long. It is *ca.* 470 km SW of the capital, Addis Ababa. The major landscape type in the study area is undulating and rugged. The watershed drains into the Omo River.

Bokole watershed lies 1160 to 2300 m above sea level (m asl), and has an annual rainfall of 1400 - 1600 mm. The lower watershed receives less rain than the upper. The temperature range in the area is 15.1 - 27.5°C (SNNPRS, BoFED, 2004), with the higher temperature in the lower part of the watershed. The soils of the study area are classified as Orthic Acrisols (SNNPRS, BoFED, 2004). The population of Bokole watershed is estimated at 11,798 (3832 in the upper, and 7936 in the lower, watershed; OoARD, 2008). Mixed agriculture is the main economic activity.

In both the upper and the lower watershed, *Zea mays L.*, *Sorghum bicolor*, *Eragrostis tef*, and *Phaseolus vulgaris* are widely cultivated. *Hordeum vulgare*, *Triticum aestivum*, *Pisum sativum, Ensete ventricosum* and *Vicia faba* are grown in the upper watershed, while *Ipomoea batatas* and *Manihot esculenta* are common in the lower watershed.

Methodology

Data were generated by means of a household survey, carried out by stratified random sampling. For this purpose, the watershed was stratified into the upper (UWS) and the lower watershed (LWS; Figure 2). In the present study, a household was defined as a basic unit of production and consumption, composed of the persons who farm common fields and live under one central decision-maker, the household head (Biruk, 2006). A list of household heads on whose land SWC structures have been implemented as new technology since 2000/01 (during which the programme started), was obtained from the agriculture and rural development office of the three *kebeles* in the *woreda*. The list from Gessa-Chare office covers households which adopted SWC structures in the UWS, whereas that obtained from Ella-Bacho and Subo-Tulama offices covers the LWS area. The list showed that SWC structures were implemented as new technology by 337 households (hh; of which 106 were in the UWS and 231 in the LWS) between 2000-2009. Of farmers who adopted SWC structures, 27% (29 hh in the UWS and 62 hh in the LWS) were selected by lot (the serial number of each hh was written on a piece of paper, wrapped, mixed and withdrawn randomly). For the group discussion, however, participants were selected on two criteria: the geographic location of the hh within the watershed management unit (hh from different corners of the target area were included), and the age of structures on the farmers’ plot of land (range of farmers on whose land the SWC structures have been implemented in different years).

A semi-structured questionnaire was prepared, covering interventions for improving or maintaining cropland productivity, and the effect of SWC structures on cropland productivity, and was pre-tested before the actual interview was conducted. It was therefore possible to modify the questionnaire on the basis of the farmers’ responses. Because the interview was conducted in the field, observation of the structures was important for improving understanding and explanation. Using a checklist, three group discussions were held. Each group was composed of ten heads of households that had adopted the structures. Information obtained from the interview and from the group discussions was checked for consistency and they were also used to supplement one another. The data collected were then analyzed descriptively by means of

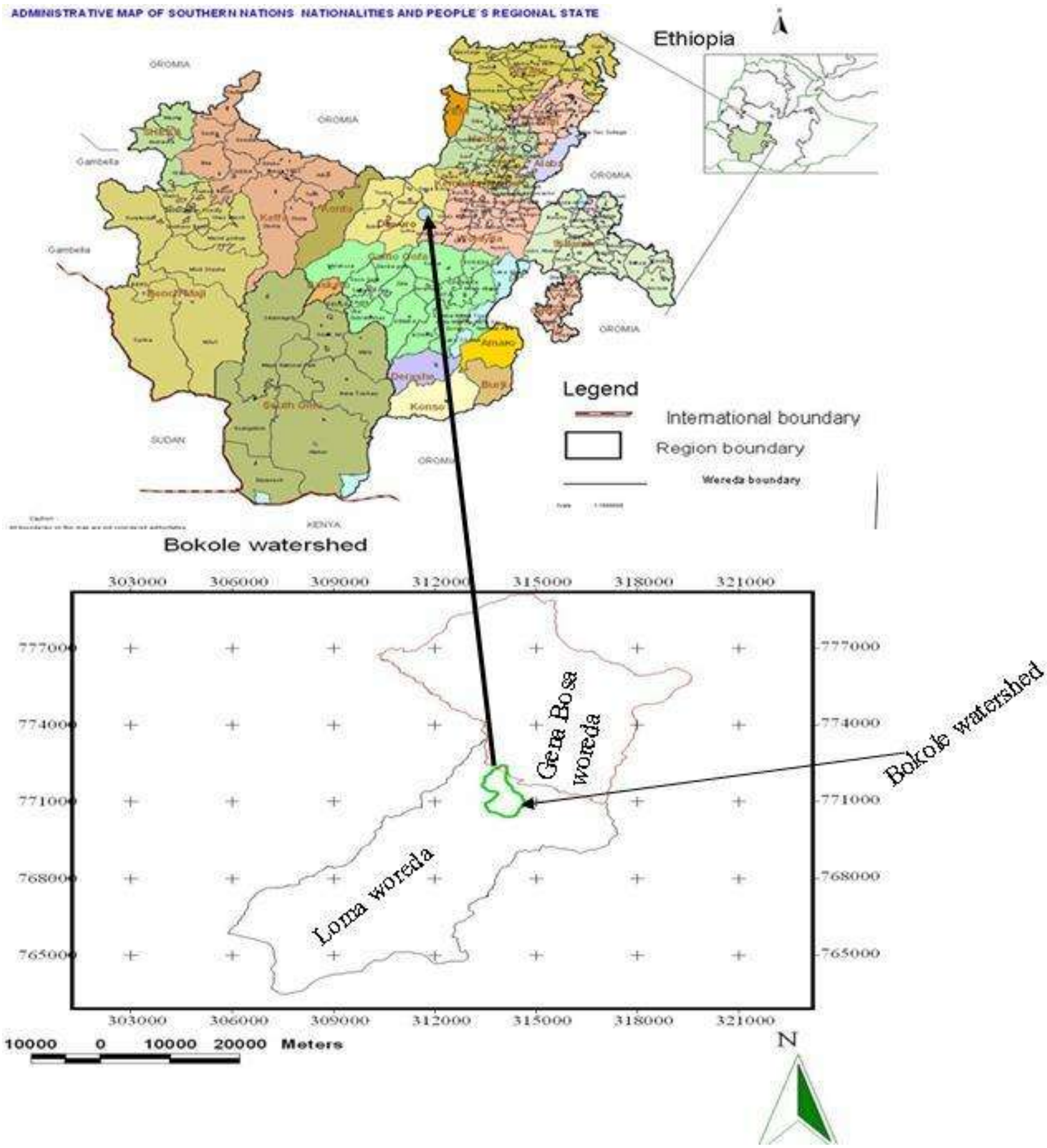


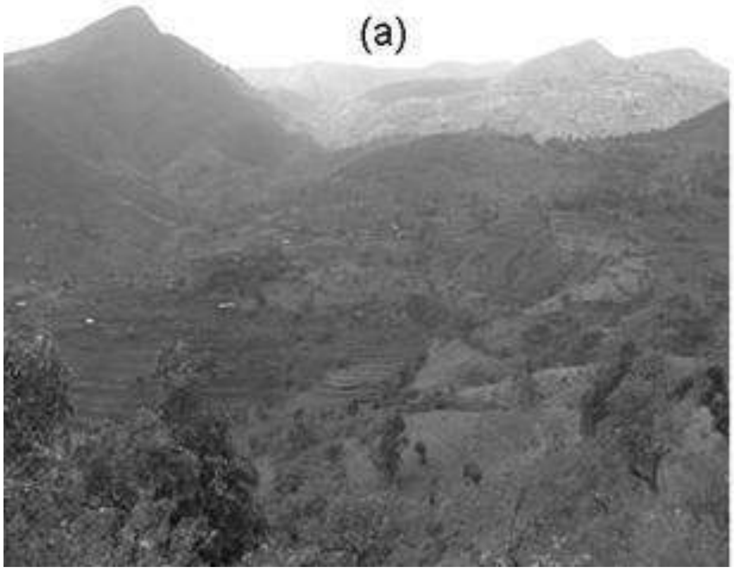
Figure 1. Location of Bokole watershed.

SPSS version 12 (2003).

RESULTS

Socio-economic characteristics in the Bokole watershed

Mean family size, mean age and mean residence period were relatively greater in the UWS as compared to the LWS. The percentage of illiterates and of those who had reached school grade 9 and above, was also higher in the UWS. The socioeconomic situation of the watershed is summarized in Table 1. The primary source of the hh income was the sale of surplus food crops (for 93.1 and 74.2% of respondents in the UWS and LWS, respectively), followed by the sale of livestock products.



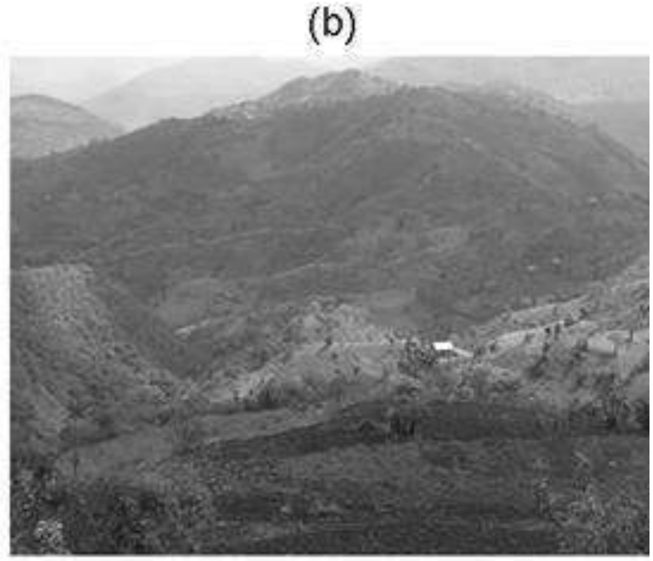


Figure 2. Partial view of the topography of the Bokole watershed, Ethiopia; upper watershed (a) and lower watershed (b).

Table 1. Socio-economic characteristics of interviewed households in the Bokole watershed of Ethiopia.

Socio-economic characteristics	Watershed category	
	Upper watershed	**Lower watershed**
Number of households interviewed	29	62
Mean family size (no.)	9.6	7.9
Mean age of head of family (year)	45.1	41.1
Mean residence period in the area (year)	38.9	31.7
Source of income		
Primarily sale of surplus crop yield	93.1	74.2
Primarily sale of livestock and its product	0.0	14.5
Secondly sale of livestock and its product	82.8	59.7
Education level of family head		
Illiterate (%)	62.1	41.9
First cycle primary (1-4 grades) (%)	13.7	29.1
Second cycle primary (5-8 grades) (%)	13.6	22.6
High school (grade 9 and above) (%)	11.3	6.4
Mean farm area owned per household (ha)	3.0	2.1
Mean number of cattle owned per household	6.6	5.1
Mean number of goats owned per household	0.6	2.0
Mean number of sheep owned per household	2.0	0.3
Mean number of equines per household	0.2	0.3

The sale of livestock products was the primary source of income for 14.5% of LWS residents, but was the second income source for 82.8% in the UWS and 59.7% in the LWS. In general, in Bokole watershed, *ca.* 99% of farmers' primary income was from agriculture (Table 1).

Practices and technologies for crop and soil fertility management

In both the UWS and the LWS, the majority of respondents practice most crop and soil management

Table 2. Exercised practices and technologies for crop and soil fertility management in Bokole watershed of Ethiopia

Crop and vegetation and soil management activities	Respondents practicing the activity (%)	
	Upper watershed	Lower watershed
Crop rotation	100	82.3
Intercropping	86.2	88.7
Fallowing	79.3	38.7
Tree planting	93.1	96.8
Commercial fertilizer	79.3	72.6
Compost	13.7	14.5
Organic matter (animal manure, household refuse)	93.1	90.3
Not using cowdung for fuel	69.0	90.4
Not using crop residue for fuel	3.5	9.7
Adopted level soil bund	93.1	21.0
Adopted stone bund	-	67.7
Adopted both level soil bund and stone bund	6.9	11.3

Table 3. Farmers' indicators to evaluate SWC structures effect in Bokole watershed of Ethiopia

Watershed category	Farmers' indicators/observations	Frequency	Per cent
Upper watershed	Crop performance and yield	23	79.3
	Extent of runoff and erosion	4	13.8
	Both (the above two)	1	3.4
	Sediment accumulation near structures	1	3.4
Lower watershed	Crop performance and yield	30	48.4
	Extent of runoff and erosion	14	22.6
	Both (the above two)	3	4.8
	Sediment accumulation near structures	3	4.8
	Crop performance and yield and sediment accumulation near structures	5	8.1
	Extent of runoff and erosion and sediment accumulation near structures	7	11.3

activities either to improve or to maintain crop yield. In the upper watershed, LSB (Figure 3) was widely practiced, whereas SB (Figure 4) was implemented by a majority of respondents in the LWS. Table 2 presents activities such as crop rotation, intercropping and fallowing, that were practiced in the study area to maintain or enhance agricultural crop yield.

Farmers' indicators, perception of crop yield and effects of SWC structures

In their plot of cropland under their own management, farmers used their own criteria or indicators to evaluate the effect of introduced SWC structures on maintaining or changing crop yield. Observation of crop performance and yield, extent of runoff and erosion, and sediment accumulation near structures, was commonly used for evaluation (Table 3).

In both the UWS and the LWS, crop performance and yield observation were major indicators of whether the introduced SWC structures had decreased, maintained, increased or led to fluctuations in soil fertility and crop yield. The perceptions of farmers concerning crop yield change, and the role of SWC structures that improve soil for better crop yield, are further treated in what follows.

Opinion on crop yield change

In the household survey, interviewed farmers were reques-ted to respond concerning the effects of constructed SWC structures on their cropland, in maintaining or improving soil fertility and thus crop yield. The choices for expressing an opinion were: decrease, maintain, increase and fluctuate. For this opinion, farmers were given the opportunity to compare the situation with other non-ter-raced cropland, and with conditions on the same land before SWC structures were implemented. A decrease in crop yield was observed only in the LWS,

Figure 3. Typical level soil bunds in upper watershed; (a) newly constructed (b) 6 years old and planted with grass.

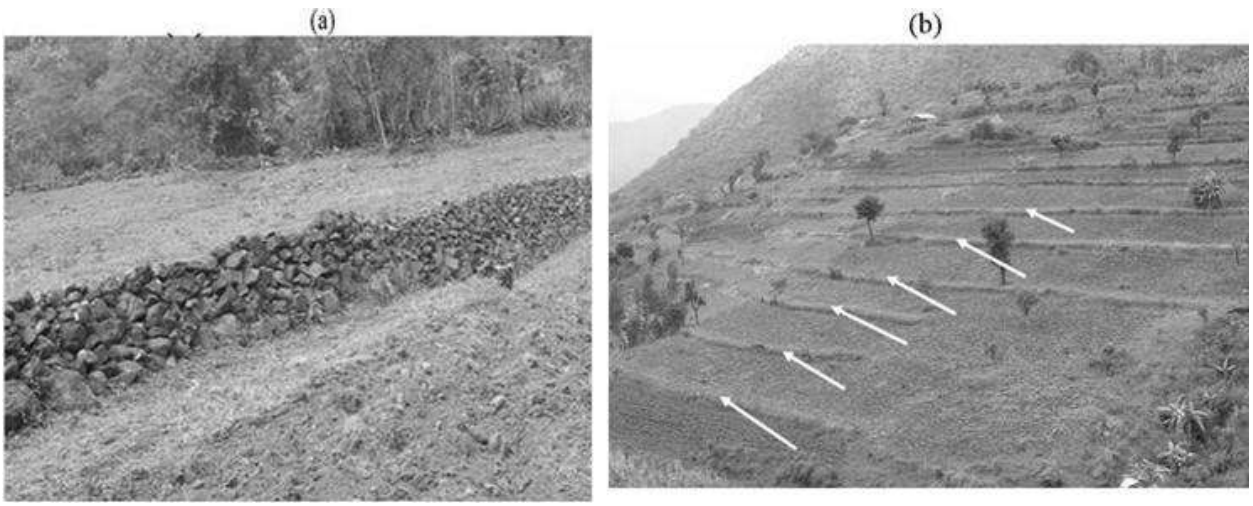


Figure 4. Stone bunds in lower watershed; (a) newly built stone bund; (b) series of stabilized stone bunds with grass, six years after construction.

whereas 'maintenance' and 'fluctuation' were perceived by a relatively high proportion of respondents in the UWS as compared to the LWS. In general, in both the UWS (79.3%) and the LWS (87.1%), a majority of respondents had a positive opinion about the effect of SWC structures on crop yield (Table 4).

For the responses 'increase' and 'fluctuate', farmers were requested to give an opinion on how long they perceived that the SWC structures had taken to improve soil fertility and crop yield. The observed effect was immediate, in the opinion of a majority of respondents (74.5%) in the UWS, and took place in not more than a year. But a majority of respondents in the LWS observed a yield increase between one and two years after the construction of structures (Figure 5).

Opinions on the roles of SWC structures

The role played by SWC structures in improving crop yield was in the reduction of runoff and soil loss, as perceived by 27.6 and 54.0% in the UWS and LWS, respectively. The combination of reduced runoff and soil loss and water retention ability, were perceived to improve crop yield by 72.4 and 46.0% of respondents in the UWS and LWS, respectively.

Table 5 presents opinion concerning the effect of structures ('decrease', 'maintain', 'increase' and 'fluctuate')

Table 4. Respondents' opinion on effects of SWC structures on crop yield (in Bokole watershed of Ethiopia).

Watershed category	SWC structures effect on crop yield	Frequency	Percent
Upper watershed	Decrease	-	-
	Maintain	2	6.9
	Increase	23	79.3
	Fluctuate	4	13.8
Lower watershed	Decrease	5	8.1
	Maintain	1	1.6
	Increase	54	87.1
	Fluctuate	2	3.2

Table 5. Opinion on effect of structures on crop yield versus its age in upper watershed (UWS) and lower watershed (LWS); (n = 29 and 62 in upper and lower watershed, respectively).

	Decrease (%)		Maintain (%)		Increase (%)		Fluctuate (%)	
Age of structure (year)	UWS	LWS	UWS	LWS	UWS	LWS	UWS	LWS
1	-	-	-	-	3.4	6.5	-	-
2	-	-	-	-	3.4	9.7	-	-
3	-	-	-	-	10.3	17.7	-	-
4	-	1.6	3.4	-	10.3	12.9	-	-
5	-	-	3.4	1.6	10.3	17.7	-	-
6	-	1.6	-	-	6.9	16.1	-	3.2
7	-	1.6	-	-	20.7	3.2	13.8	-
8	-	3.3	-	-	6.9	3.2	-	-
9	-	-	-	-	6.9	-	-	-
Total	-	8.1	6.9	1.6	79.3	87.1	13.8	3.2

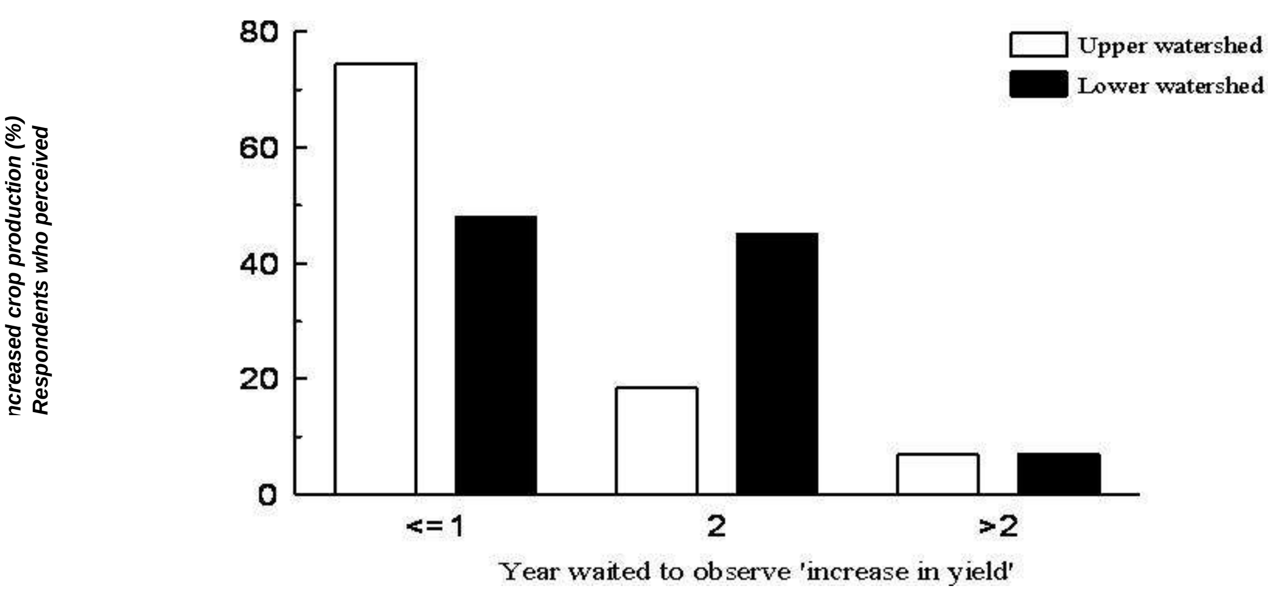


Figure 5. Response on period to observe increased crop yield (n = 27 and n = 56 in upper and lower watershed respectively).

on crop yield after construction, relative to the age of structures. Some of the farmers who owned structures 1-9 years old (in the UWS) and 1-8 years old (in the LWS), perceived an increase as a result of the structures.

‘Fluctuation’ was observed by farmers who owned structures six and seven years old. In the LWS, a decrease was observed on cropland on which structures were four years old and above.

Does increased yield compensate for the ‘lost cropland’?

A majority of the respondents in both parts of the watershed perceived that SWC structures improved cropland and thus crop yield. It is practically observable that the structures, LSB and SB, occupy a proportion of cropland area, and consequently reduce the area available for cultivation and crop production. However, 100% of farmers in the UWS, and 91.0% in the LWS, perceived that increased yield compensated for the ‘lost land’.

Increased crop production in the area between structures, as a result of conserved soil and moisture, was a major justification for their use, and was perceived by 66.7 and 60.7% of respondents in the UWS and LWS, respectively, as compensation for the ‘lost land’. An alternative assumption was that in the absence of structures, the entire cropland area might be seriously eroded and degraded, and crop yield would be expected to decline, taken as justification by 26.0 and 37.5% of respondents in the UWS and LWS, respectively. In the UWS, 7.3% of farmers considered grass harvesting to be an advantage conferred by LSB as part of the compensation for ‘lost land’.

DISCUSSION

Soil and crop management experiences for crop production

Frequent cultivation and soil erosion may reduce the soil fertility of agricultural land in the course of time. To overcome such problems, more than 70% of the interviewed hhs in both the UWS and the LWS practice crop rotation, add organic matter (animal manure, household refuse) to their farms, and use commercial fertilizer (Table 2).

A point raised during the group discussion was that farmers in the LWS appreciate the role of SB for their effect in increasing the efficiency of commercial fertilizer on crop response. This was because SWC structures increase the retention of moisture and soil particles, together with fertilizer, within cropland which might otherwise be washed away by water erosion.

Many farmers (69.0 and 90.4% in the UWS and LWS, respectively; Table 2) did not use cowdung for fuel, but instead used it to improve soil fertility, which increases the possibility of enriching soil with organic matter. In most cases, however, organic matter, including cowdung, is applied around the homestead, hence plots far from the homestead may not benefit. The use of crop residues for fuel by the majority of farmers in both the UWS and the LWS (Table 2), which would otherwise remain on cropland, is expected to affect soil fertility adversely. Aklilu and Graaff (2006b) indicated that the use of crop residues for fuel leads to a deterioration in soil-biological processes which contribute substantially to soil fertility.

Continuous cultivation depletes plant nutrients and makes soil prone to erosion. Farmers appeared to have understood this, and had developed the custom of periodically fallowing cropland as a land-management practice for obtaining better yields. Fallowing was more prevalent in the UWS (79.3%), as compared to the LWS (38.7%; Table 2). The critical factor in the system of fallowing is the length of the fallow period (Morgan, 2005); in the study area, farmers wait (according to the group discussion) three to four years, which was sufficient to restore soil fertility to some extent. However, the fallow land was usually used for intensive free grazing, which would presumably degrade by trampling and removing vegetation cover. The frequency and length of fallowing commonly depend on the area and productivity of the cropland.

In the study, watershed, the average land-holding owned in the UWS was relatively larger (3.0 ha) than that in the LWS (2.1 ha; Table 1), which may have encouraged farmers in the UWS to undertake such practices to a greater extent than those in the LWS. In contrast, as was observed in the field, the trend of constructing SWC structures by investing their own resources, and of maintaining existing structures was ‘poor’ in the UWS as compared to the LWS. Relatively better climatic conditions in the UWS (especially better moisture and moderate temperature) and the possession of a larger area of farmland, may have contributed to reduced attention to SWC.

Introduced SWC structures and their distribution

LSB were the dominant structures (93.1%) constructed in the UWS, mainly because of a shortage of stone to construct SB. The development agents and some farmers stated during the survey that *Fanya juu* was introduced on a few farmers’ cropland, but most of it failed or was broken shortly after construction, owing to the nature of the structure, and its liability to damage on steep land. LSB were relatively ‘better functioning’, are more accepted than *Fanya juu* in this part of the watershed, and consequently are constructed on the majority of the adopters’ land (Table 2). In the LWS, SB was the dominating structure among the introduced technologies, mainly owing to the availability of stones on cropland for building such structures, and to their stability after construction when compared with LSB and *Fanya juu*.

Farmers opinion on LSB and SB effect on soil and crop yield

A core aim was to evaluate the perceptions of the farmers concerning crop yield: whether it decreased, increased or fluctuated. Generally, farmers believed that LSB and SB resulted in an increase in crop yield. The various reasons for this, and the farmers' arguments, are given below.

A decrease in crop yield was perceived in the LWS by only 8.1% of respondents on whose land the SB were four years old and more (Table 5). The reasons given for this were not ineffectiveness of the structures *per se*, but their incorrect implementation and the lack of complementary practices. These include, as conceived by the respondents, a lack of cut-off drains upslope to reduce the volume of incoming surface runoff, and the continuous cultivation of cropland without complementary inputs.

During group discussions in the LWS, a farmer said 'a terrace has a double function for many people in our kebele: the soil becomes fertile due to reduction of erosion, and the grain incentive for the labourer supported the household economy.' A majority of the respondents (79.3% in the UWS and 87.1% in the LWS) perceived that these structures improved crop performance (Table 4). Such an effect was perceived by respondents irrespective of the age of the structures they owned, in both the UWS and the LWS (Table 5). In the group discussion and the interview, crop yield and performance, and reduction of surface runoff and erosion in the inter-structure area, were used as indicators to evaluate SWC structures (Table 3).

In a similar study in northern Ethiopia (Alemayehu, 2007), the majority of the interviewed farmers responded that terraces increased soil fertility, improved moisture status and increased crop yield. Furthermore, in the Gunono area of Wolaita in southern Ethiopia, 80% of the farmers were of the opinion that soil bunds increase yields (Esser et al., 2002). The study conducted by Nyssen et al. (2006) in northern Ethiopia showed that 75.4% of the farmers were in favour of stone-bund building on their land, which is a clear indication that the local community perceives this con-servation measure as beneficial. Another survey in Hagere Selam, Tigray by Esser et al. (2002) also showed that 80% of farmers responded that investments in SWC were profitable, and 68% were of the opinion that conservation practices led to increased yields in normal years. A related study by Woldeamlak (2006) showed that *ca.* 94% of the interviewed farmers in northern Ethiopia believe the physical SWC measures have the potential to improve cropland productivity, and lead to increased crop yield.

Since the gradient of most farmland in the watershed is steep, there is an increasing tendency towards erosion. The channel of the LSB traps and retains surface runoff from the upslope area, which would otherwise erode everything within the cropland. In the LWS, the soil is shallow, and experiences low rainfall and recurrent drought. Thus, the role of structures in reducing runoff, reducing soil loss by water erosion and retaining water, was noted by farmers as improving agricultural production in both the lower and upper watershed areas.

Even though a relatively small proportion of the interviewed farmers perceived the structures negatively, most of their reasons for this were related to management of the structure itself. One of the negative views was 'fluctuation' in crop yield, which was stated by 13.8 and 3.2% in the UWS and LWS, respectively (Table 4). According to the respondents, within three years after construction of the structures, crop yield increased, but subsequently decreased; this was observed by farmers who owned structures six and seven years old. This was predominantly the case in the UWS as compared to the LWS, and was supported with the reason that the channel behind the embankment of the LSB became filled with sediment in the long term (because little attention was given to removing the sediment) with the result that surface runoff overtopped the structure. Thus, in this case, the observed improvement during the earlier life of the structure was reversed or decreased later, owing to the resumption of erosion.

In both the UWS and the LWS, the fluctuating effect of the structures was perceived on structures six and seven years old (Table 5), suggesting that, unless proper management is carried out, their efficiency will decline with time, because they will be broken or sediment will accumulate, leading to overtopping by surface runoff.

Period required to induce increased crop yield and sustainability

The period required to observe the perceived yield increase after the construction of structures varied between the UWS and the LWS. In the UWS, most of the respondents (74.5%) perceived that change was observed after one year, and a few (18.5%) waited for two years. In the LWS improvements observed within a one-year and a two-year period were comparable (48.0 and 45.0% respectively). Araya and Asafu-Adjaye (1999) estimated that a positive net economic benefit as a result of soil conservation measures was obtained after two years from their construction, which is in line with the present study. Natural conditions, such as shallow workable soil, low moisture retention capacity and erratic rainfall, influenced the rate of cropland response after construction of structures in the LWS. Since the channel is empty in a newly constructed LSB, it is more efficient in trapping water and soil. Therefore, the rate of reduction of surface runoff, and thus the retention of soil and water increases, and corresponding subsequent effects accrue. Newly built SB is porous, and their ability to retain water and surface runoff is less than that of LSB (Figure 4a). Eventually, the pore space becomes filled with sediment, more runoff is impounded, and the sediment retained behind bunds enhances vegetation growth (Figure 4b). Thus, the effect of SB was gradualyl compared with LSB.

Since farmers in a subsistence economy accept and use conservation technologies that enhance productivity and provide short-term benefits (Aklilu and Graaff, 2006b), the perceived increase in yield within a few years, for both LSB and SB, may encourage them to continue to adopt it. In both watersheds, only 7.0% of respondents must wait more than two years to observe increased yield. The question is 'how long the increment would be sustained under certain land management conditions?' In the LWS, SB created a fertility gradient in the inter-structure area (as noted in the group discussions), that is, fine soil accumulated in the upslope part of bunds. On the one hand, this was due to tillage erosion related to the surface gradient, and was aggravated by the number of boundaries created (Nyssen et al., 2000; Desta et al., 2005; Li et al., 2006). On the other hand, soil erosion from the upper slopes in the inter-structure area removes fertile soil, whereas excessive accumulation occurs on the lower slope. Such a fertility gradient problem of SB has been reported by other researchers (Nyssen et al., 2006). McConchie and Huan-cheng (2002) also reported that rock terraces trap a greater thickness of soil on the slope, increasing the risk of slope failures, reducing moisture and nutrient availability to plants, and thinning the soil upslope.

To cope with such problems, farmers in the LWS adopted the interesting practice of shifting the position of a SB five to eight years (depending on slope and soil conditions) after its construction. In this practice, they move the position of a SB some distance downslope (about one-third of the distance from the upslope SB on the lower side) and re-build it. The accumulated fine and fertile soil behind the bund and in the spaces between the stones of which the SB is constructed, is spread on the previously denuded area (eroded area). Such cyclic activity interrupts the long-term benefits of a terrace, which is expected to develop progressively to a bench terrace (with a reduced slope gradient), the development of vegetation cover on the bunds themselves and the change in land management. However, the logic, as explained by McConchie and Huan-cheng (2002), which states that a soil several metres deep produces no more than a soil only deep enough to accommodate the roots, reinforces the farmers' practice. Destruction of SB, to redistribute the entrapped soil, and the practice of re-construction, was also reported by Aklilu and Graaff (2006b) from the Baressa area, Ethiopia.

In the case of LSB, the sustainability of increased yield depends on management of the structure, the removal of sediment from the channel and the repair of broken embankments. When the channel accumulates excess sediment, the function of LSB will either cease or become less effective.

Productions and functions of structures to compensate 'lost' land

SWC structures have commonly been condemned, as they occupy a considerable area of productive land (Herweg and Ludi, 1999). In contrast, a majority of farmers in both the UWS and the LWS of the study area did not complain. Instead, their perception (100% in the UWS and 91.0% in the LWS) is that the increased yield that results from LSB and SB compensates for the crop yield from the lost or uncultivated land.

This opinion is in line with that expressed by McConchie and Huan-cheng (2002), that the reduction in potentially productive land may be partly offset by an increase in production from the flatter land created by terracing. The main assumptions of farmers in the study area were that, in the absence of bunds, the entire farmland area would suffer a significant reduction in yield, and that crop production improved as result of their construction. In addition, the cropland occupied by bunds was not considered idle or non-productive on many of the respondents' fields, because planted or naturally growing grass and other plants were harvested.

Conclusions

The household survey and group discussions of the present study revealed that, in the study area, watershed management activities, particularly LSB and SB, have a positive effect on combatting soil erosion, and a potential for sustainable land management towards the improvement of crop productivity, if they are properly managed. The advantages of these introduced structures outweighed their side-effects in the period during which farmers observed their performance. About 79.3% of respondents in the UWS and 87.1% in the LWS recognized that the structures had improved the soil and crop production by reducing soil loss and conserving water.

In both the UWS and the LWS, farmers perceived that, according to their own criteria for evaluating the effect of the structures, in most cases it will not take more than two years to improve land on which the structures are built. The performance of crops or natural grass, the presence or absences of signs of runoff and erosion in the inter-structure area, and the accumulation of sediment near structures, were frequently used evaluation criteria. These criteria in turn indicate a reduction of soil loss from cropland and improved soil moisture retention. Complaints about 'lost land' or land occupied by terraces were few, because of the above-mentioned advantages of the structures.

The criticisms raised concerning introduced SWC structures by a relatively small proportion of farmers- a decrease in crop yield, an increase shortly followed by a decrease (fluctuation) or no change in land and crop yield, were related to incorrect implementation of the struc-ture and watershed management activities. The absence or incorrect construction of supporting structures, such as cut-off drains upslope of cropland, increases the volume of surface runoff on cropland in such a way that struc-tures cannot cope, and thus shortens their life and makes erosion reduction difficult. As observed during field work, neglect of periodic maintenance activities supposed to be carried out by the land user, such as removing sediment from the channel, repairing the embankment and the SB, reduced the effectiveness of the structures.

Effective watershed management activities, including SWC structures, are of substantial benefit for attaining and sustaining food security in smallholder farming, through the successful rehabilitation and management of natural resources. In this context, farmers' perceptions are critical. Therefore, there is a need for awareness creation, and for monitoring the proper management of the existing structures, to ensure that they function as intended, and to improve their efficiency. This can reduce 'decreased' or 'fluctuating' crop yield. In addition, suitable conservation structures, adapted to climatic conditions and slope gradient, need to be implemented. Further research should be carried out to investigate other benefits of the structures, e.g. social benefits. An econo-mic analysis of costs and benefits would provide a better overall insight.

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