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Impacts of long-term soil and water conservation on agricultural productivity: The case of Anjenie watershed, Ethiopia

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ABSTRACT

Over the last three decades, many soil and water conservation projects have been implemented in various parts of eastern and southern Africa to control land degradation, and improve land productivity, especially under 'catchment approach' initiatives of the 1980s. In Ethiopia, many of these soil conservation projects were implemented following the severe drought of 1974. To capture long-term impacts of these initiatives, a study was conducted in Anjenie Watershed of Ethiopia, assessing fanya juu terraces and grass strips constructed in a pilot project in 1984, and which are still functional 25 years later. Data were collected from government records, field observations and questionnaire surveys administered to 60 farmers. Half of the respondent had terraced farms in the watershed former project area (with technology) and the rest were outside the terraced area (without technology). The crops assessed were teff, barley and maize. Cost–benefit analyses were used to determine the economic benefits with and without terraces, including gross and net profit values, returns on labour, water productivity and impacts on poverty.

The results indicated that soil and water conservation had improved crop productivity. The average yields on terraced fields for teff, barley and maize were 0.95 t ha^{-1} (control 0.49), 1.86 t ha^{-1} (control 0.61), and 1.73 t ha^{-1} (control 0.77), respectively. The net benefit was significantly higher on terraced fields, recording US$ 20.9 (US$ −112 control) for teff, US$ 185 (US$ −41 control) for barley and US$ −34.5 (US$ −101 control) ha^{-1} yr^{-1} for maize, respectively. The returns on family labour were 2.33, 1.01 and 0.739 US$ man-day^{-1} for barley, teff and maize grown on terraced plots compared to US$ 0.44, 0.27 and 0.16 man-day^{-1} for without, respectively. Using a discount rate of 10%, the average net present value (NPV) of barley production with terrace was found to be about US$ 1542 over a period of 50 years. In addition, the average financial internal rate of return (FIRR) was 301%. Other long-term impacts of terracing included farmers' growing of maize on terraced fields as a result of water conservation. Currently, farmers also grow barley on terraced fields for two crop seasons per year unlike the experiences on farms without terraces. Household incomes and food security had improved and soil erosion drastically reduced. Many farmers had adopted terracing doubling the original area under the soil conservation pilot project and consequently improving environmental conservation in the watershed.

1. Introduction

Agricultural development in Ethiopia is hampered by many factors among which land degradation is the major one, threatening the overall sustainability of agricultural production in the country (Nyssen et al., 2004). Ethiopia is a mountainous country with a substantial proportion of its land (45%) in highland zones at altitudes exceeding 1500 m above sea level (masl). Due to the mountainous and rugged terrain, the country is highly prone to land degradation. Among the different forms of land degradation processes in Ethiopia, soil erosion by water is the most serious, threatening food security, environmental sustainability and prospects for rural development in the country.

In Ethiopia, soil erosion is a phenomenon as old as the history of agriculture in the country (Hurni, 1990). Ethiopia has been illustrated as containing some of the most seriously eroded areas in the world (De Graaff, 1996), with an estimated annual soil loss of about 42 tones (t) per hectare (ha) per year (yr) from croplands, resulting in an annual loss of 1–2% crop production (Hurni, 1993). The

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Table 1
Some climatological parameters of Anjenie Watershed.

Months/parameters	Average min. monthly temp. (°C)	Average max. monthly temp. (°C)	Average monthly temp. (°C)	Rainfall (mm)	Evaporation (mm)
January	6.3	24.3	15.3	5.9	162.6
February	7.7	25	16.3	11.6	161.3
March	9.1	26.9	18	31.4	240.8
April	8.5	26.5	17.5	48.3	290.8
May	11.5	24.9	18.2	108.8	174.1
June	10.5	20.6	15.5	239.1	58.4
July	10.2	18.4	14.3	402	29.0
August	10.5	18.1	14.3	356.1	28.8
September	10	19.8	14.9	239.7	34.4
October	8.1	21.7	14.9	108.8	60.9
November	5.7	22.4	14	28.1	102.8
December	4.2	23.5	13.8	17.6	155.1
Total/averg.	8.5	22.7	15.6	1597.4	1502.0

Source: SCRP 8th Progress Report, Vol. 9, 1991.

problem of land degradation is particularly critical in the highlands. The frequent incidents of famine and starvation in Ethiopia have partly occurred due to soil erosion (Hurni, 1990).

Despite the wide spreading of soil erosion, soil and water conservation was largely neglected in Ethiopia prior to 1974. The problem attracted the attention of policy makers only after the disastrous drought and famine of 1974. Based on this incidence, the Ethiopian government decreed land reforms in 1997, and initiated massive soil conservation program. Since then investments in soil and water conservation have been made by governmental and non-governmental organizations and improvements are observed (Nyssen, 1998; Afework, 2005).

Investment in soil and water conservation contributes to intensification of agricultural systems, enhances food production and alleviates poverty. In particular, terrace technologies control soil erosion by reducing the slope of the cultivated land and this facilitates the conservation of moisture for crop use, which, in turn, leads to increased crop yields. Cognizant of these potentials, huge investment has been made in different parts of the country.

However, the adoption rates of soil and water conservation technologies show mixed results. Terrace technologies are well adopted by farmers and doing well in specific environments and socio-economic contexts. On the other hand, the adoption rate has been very low in other areas due to diverse perceptions of farmers regarding the threat of soil erosion, household size, land and farm characteristics, technology-specific attributes, land quality differentials and tenure insecurity (Bekele and Holden, 1998).

A number of biophysical research activities in soil and water issues have been conducted in the Anjenie watershed; however, impacts of such soil and water conservation initiatives on improving yields and incomes of the beneficiary households remained largely un-quantified. This study was initiated to bridge this knowledge gap. The main objective of this study, therefore, was to quantify the contribution of long-term soil and water conservation initiatives on crop productivity, profitability returns to investment, and socio-economic implications in improving rural livelihoods in Ajenie watershed.

2. Materials and methods

2.1. Description of the study area

Anjenie watershed is located in the central highlands of Gojjam, Amhara Region of Ethiopia, about 37°3′E, 10°4′N and about 260 km south east of Bahir Dar town. The watershed lies at altitudes of about 2400 masl. The watershed covers an area of 108 ha but the size of the study area is about 113.4 ha. It is the home of 95 households having a total population of about 512. The average annual climatic parameters of Anjenie watershed such as temperature, precipitation and evaporation are indicated in Table 1. On average, the major rainfall during the rainy season, between June and September, accounts for 75% of the total annual rainfall. The soil types in Anjeni are dominantly Alisols (41%), Nitosols (24%), Regosols and Leptosols (12.4%), and Cambisols (19%). All soils in Anjeni have high clay content. They are generally acidic (pH_{H_2O} 4.99–5.72) and relatively low in organic carbon content (1–2.2%). Moreover, they have low to medium total nitrogen (0.11–0.26%) and plant available phosphorus content (0.94–4.9 ppm) (Zeleke, 2000). These facts indicate the overexploitation of soils and leaching processes (Ludi, 2004; Haile et al., 2006). The average amount of diammonium phosphate and urea fertilizers applied for most cereals in Anjenie watershed is about 70 and 18 kg ha^{-1} yr^{-1}, respectively.

Soil and water conservation measures include fanya juu terraces and grass strips constructed in 1984 by the Soil Conservation Research Project (SCRP) which was initiated by Bern University of Switzerland in collaboration with the Ethiopian Ministry of Agriculture. Fanja juu terraces are earth embankments, created by digging a trench about 60 cm wide along the contour, and throwing the soil upslope to form ridges (Mati, 2007). Terraces were constructed by the unpaid participation of the local communities. A study by Herweg and Ludi (1999) on terraced fields indicated that soil losses in the period from 1983 to 1999 have ranged from 17 t ha^{-1} up to as high as 176 t ha^{-1}.

Agricultural systems in the study area are typical of both the upland cereal-based system and the smallholder crop-livestock mixed system of agriculture, growing barley, wheat, teff, maize and legumes as major crops. Teff and barley are the predominantly cultivated crops followed by maize and wheat. Over 80% of the cultivated area is occupied by cereals. Oil crops and legumes are cultivated on smaller areas (Kohler, 2005). The average land holding is significantly lower than 1 ha. Before the introduction of terraces, farmers faced serious soil erosion problems which adversely affected the availability of soil moisture and the status of soil nutrients. This led to poor crop yields and low land productivity. As a result, food insecurity and poverty have become common problems.

Anjene watershed was selected for this study because nearly all the households in the watershed had adopted terracing. The area is a model site for soil and water conservation activities for the Amhara region as well as the nation. Moreover, the terraces at Anjenie are well-maintained and there has been expansion of newly terraced farm lands in the surrounding villages since the project terminated.

2.2. Data collection methods

Field data were collected in the Year 2009 during the months of August to October. For this purpose, Anjenie watershed was divided into three sampling strata; the upper, middle and lower part of the watershed. This is because the upper zones are steeply sloping, but the slope decreases as someone moves down the watershed profile. From each stratum, farmers growing the test crops teff, barley, and maize were selected using the purposive sampling techniques. Questionnaire surveys were administered to 10 farmers randomly selected from each stratum of the watershed. Another 10 farmers were also interviewed from adjacent un-terraced farmlands (without) for comparison which were similarly stratified in to upper, middle and lower watershed areas. In total, 60 farmers were interviewed across the two treatments (with and without terracing). Accordingly, samples households "with terrace treatment" made about 35% of the total households in the watershed. Other secondary data such as general information about the watershed was collected from records kept by the Regional and District Agricultural Office, as well as from published and unpublished reports on terracing, farming systems and other socio-economic factors. Further, group discussions were undertaken with extension staff and leaders in the watershed. Collected data were then analyzed using descriptive statistic techniques.

2.3. Defining the different economic terms

To investigate the profitability of investment on terrace, a cost–benefit analysis (CBA) was calculated. The basic idea was to find out if the investment on terrace including yearly maintenance costs is justified in terms of a higher agricultural production and agricultural incomes (benefits). It was computed using the average prices of inputs and outputs. Such analysis was then complemented with other types of financial analysis such as net present value (NPV), internal rate of return (FIRR) and return on investment (ROI) and marginal rate of return (MRR) (Leiber, 1984).NPV compares the value of a monetary unit today with the value of that same dollar in future (discounting), taking inflation and returns into account. The difference between the sum of all discounted benefits and costs represents the NPV. This difference reflects how much the investment has brought benefits. If the NPV is positive, it means the investment on terrace was profitable. However, if NPV is negative, clearly the costs outweigh the benefits and this means the investment on terrace was not economical.

While NPV is expressed in monetary units (Dollars, for example), the FIRR is the true interest yield expected from an investment in terrace expressed as a percentage. It shows the discount rate below which an investment results in a positive NPV, and above which an investment results in a negative NPV. It is thus the break-even discount rate, the rate at which the value of costs equals the value of benefits. A simple decision-making criterion to accept the profitability of the investment is the FIRR exceeding of the cost of capital; and it is rejected if this FIRR is less than the cost of capital.

ROI is a performance measure used to evaluate the efficiency of an investment. It is the ratio of money gained or lost on an investment relative to the amount of money invested. To calculate ROI, the benefit (return) of an investment is divided by the cost of the investment; the result is expressed as a percentage or a ratio. That is, if an investment on terrace does not have a positive ROI, then the investment should not be undertaken.

Marginal rate of return was calculated to quantify the rate of return generated by every currency unit of investment in terrace as compared to the one without terrace. The marginal rate of return was thus computed by expressing the difference between the net benefit with and without terrace as a percentage of the difference of total costs. The computed marginal rate of return gives an indication of what a producer can expect to receive, on average, by switching technologies. Hence, a 150% marginal rate of return in switching from without terrace to with terrace implies that for each dollar invested in terrace, the producer can expect to recover the US$ 1 invested plus an additional return of US$ 1.50. For all calculations, the cost of family labour was calculated on the basis of US$ 0.93 man-day^{-1} which is the opportunity cost of labour in the area.

Social and environmental benefits accruing as a result of terrace such as reduced flood problems in the downstream farm lands, increased stream base flow during the dry season, ground water recharge were not included in this impact assessment study.

3. Results and discussions

3.1. Viability for improving productivity

Values of crop yield for terraced and un-terraced treatments and across the slope strata are presented in Fig. 1. The mean yields of teff, barley and maize on terraced fields were 0.95, 1.86 and 1.73 t ha^{-1}, respectively, while the corresponding values for un-terraced farms were 0.49, 0.61 and 0.77 t ha^{-1}. Terraced farms were obviously more productive than un-terraced ones showing an average yield increment of 94, 205 and 125%, respectively, for teff, barley and maize, as compared to those without terraces. These results are in line with the findings of Vancampenhout et al. (2006) who have also found similarly positive effect of soil conservation on crop yield in the highlands of Ethiopia. This is associated with the positive effects of terracing in improving moisture availability, nutrient supply and conservation of soils as indicated in various studies (Tilahun, 1996; Vagen, 1996; SCRP, 2000; Esser

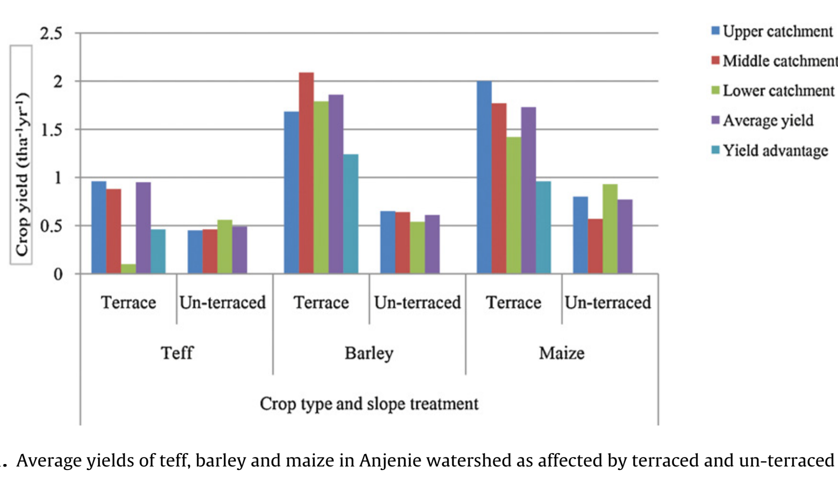

Fig. 1. Average yields of teff, barley and maize in Anjenie watershed as affected by terraced and un-terraced fields.

et al., 2002; Alemayehu et al., 2011; Posthumus and De Graaf, 2005). On the other hand, however, Herweg and Ludi (1999) and Kassie et al. (2008) found that fanya juu, soil/stone bund, grass strips did not increase crop yield and biomass production in the highlands of Ethiopia and Eritrea. These authors justified that unless productivity was increased, for example, by increasing fodder grass production on bunds, soil and water conservation measures could not be characterized as a "win-win" measure to reduce soil erosion. This is contrary to the findings of this study, in which a win-win situation was found.

There were variations of yield data along the top-sequence of the terraces, but this variability did not conclusively show a marked pattern of the different crops and treatments. The percentage yield increases showed that barley benefited the most from terracing as the yields were tripled. Another observation was that farmers having terraces could produce two crops of barley per year, in the main season and using residual moisture. This is possible because farmers plant barley early in the rainy season in the beginning of May and harvest at the end of August/beginning of September. After the first crop is harvested, farmers immediately prepare their land and sow again the second barley crop until the third week of September. The rain ceases usually by the end of September/first week of October and the second barley crop is then grown using residual moisture and harvested in December/January. Double cropping of barley was rare on un-terraced plots.

Another new development associated with terracing in Anjenie was the introduction of maize, a crop that was never grown in the watershed before the project was introduced in the 1980s. Maize is also found outside the catchment area but usually around homesteads where soil fertility is much better than in fields far from the village. The increased presence of maize crop in the watershed was associated with improvements in soil moisture and better nutrient availability within the terraced fields. Grasses grown on terraces and increased crop residues from terraces were also additional incentives for farmers, as these were utilized for livestock fodder. Generally, these results show that terracing has long-term positive effects on crop productivity through improved soil and moisture conservation. Terracing practices are generally widely accepted and disseminated in the area, thereby disputing the claims that smallholder farmers are unlikely to adopt high cost technologies unless substantial subsidy is provided (Bekele and Holden, 1998, 2001). Investment in soil and water conservation has greatly contributed to crop production and land productivity.

3.2. Viability for increasing farm incomes

Table 2 shows cost–benefits analysis (revenue, aggregated expenses and net incomes or profit) of terraced and un-terraced farms, for each of the three crops. It shows a clear advantage in terracing, especially in gross revenues. However, there were slightly higher expenses for terraced fields compared to un-terraced ones, which could be attributed to the extra costs of maintenance of the structures. The NPV showed a clear advantage of terracing, reflecting positive incomes from barley. This result is in agreement with the findings of Bekele (2005) who estimated positive contributions of level bunds compared to 'without' in Hundi-Lafto catchment of Ethiopia. But negative incomes from all un-terraced and terraced maize fields are a reality facing farmers in the region. The costs of inputs sometimes outweigh the benefits even though the added value of terracing is reflected in the yields. In addition, the values were depressed by the inclusion of family labour. These findings agree with similar ones from Kenya's Kaiti catchment (Mulinge, 2009 unpublished), where positive impacts on yields were obtained but the net incomes were negative; a factor associated with high costs of inputs, and poor commodity prices.

Table 2
Cost–benefit analysis of teff, barley and maize as affected by terraced and un-terraced fields.

Crop/treatment	Revenue US$ ha^{-1}	Expenses US$ ha^{-1}	Net profit US$ ha^{-1}
Teff			
Terraced	292.6	271.7	20.9
Un-terraced	144.1	256.3	-112.2
Barley			
Terraced	382.3	197.1	185.2
Un-terraced	98.5	139.6	-41.1
Maize			
Terraced	245.7	280.2	-34.5
Un-terraced	102.2	203.0	-100.8

3.3. Profitability analysis excluding family labour

The profitability analysis excluding family labour was calculated using the average prices of inputs and outputs. The assumption here was that rural family labour has less opportunity cost and therefore will be idle if it was not employed on own land. The respective values of net benefit (profit) are shown in Fig. 2. The benefits from crop residues and grass were also considered in this analysis because straw and grass have market value in the catchments for animal feed. The main cost components were fertilizers, seeds, labour and animal power. Farmers used their own planting material by putting aside variable seeds from previous year's harvest and they rarely bought certified seed. Therefore, the price of the seed was the average purchasing price among farmers. Sometimes herbicides were used by the interviewed farmers and hence were included in the cost–benefit analysis. Labour costs were considered for the preparation of land, planting, weeding, harvesting, threshing and marketing activities.

Teff, barley and maize grown on terraces earned overall incremental income advantage of US$ 159, 275 and 141 ha^{-1} yr^{-1} over the un-terraced farms. This indicates that though the opportunity cost of family labour was accepted to be low (US$ 0.93 day^{-1}), the share of family labour costs from the total production costs in terraced plots was significantly high. Investment in soil water conservation (SWC) can thus greatly contribute to increased income and household food security. However, the contribution of terracing to household income depends on the types of crops grown. These results are therefore inconsistent with the findings of Ludi (2004) who found that the profitability of SWC investments depends on cropping intensity.

3.4. Economic return on family labour

It was found that family labour requirements per hectare for crop production were higher in terraces than without terraces treatment (Fig. 3). This is because terracing requires more labour for construction and maintenance and it also needs additional labour for husbandry, harvesting and marketing activities for marginal output. Production of teff in terraced plots absorbed the highest amount of family labour at 203 man-day ha^{-1}, followed by maize (178 man-day ha^{-1}) and barley (135.5 man-day ha^{-1}). This was because teff requires a fine seed bed, necessitating multiple ploughing and trampling before sowing, and also frequent weeding more than barley does. Moreover, teff is the major cash crop in the area and it requires additional labour to transport to the market. There is higher family labour demand on terraced fields as compared to un-terraced ones since the terraces have to be rebuilt regularly.

One of the parameters considered in this study was the return to family labour. It is determined by subtracting all costs related to crop production from the total revenue excluding family labour inputs. Dividing this net profit with the number of family labour

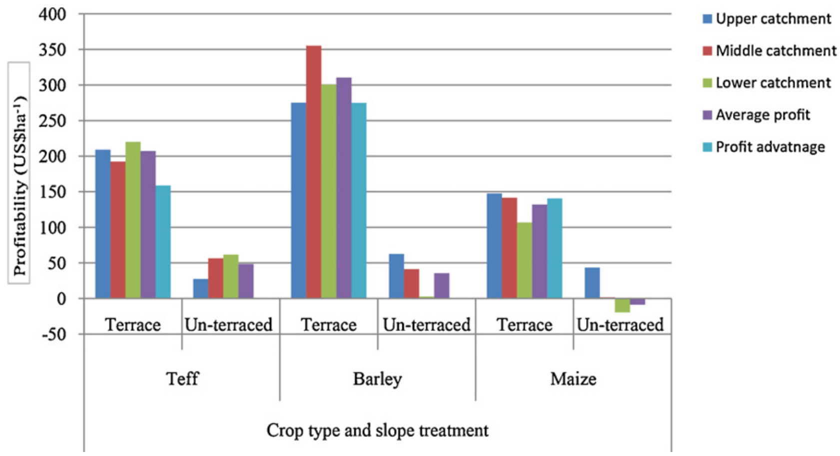

Fig. 2. Profit advantage of terraced and non-terraced farms excluding family labour expense.

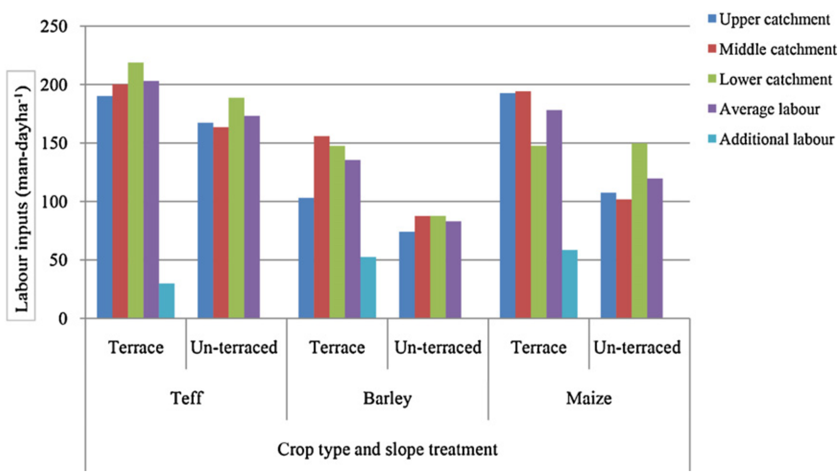

Fig. 3. Total family labour inputs for teff, barley and maize in Anjenie watershed as affected by terraced and un-terraced fields.

inputs in man-days gives gross return to family labour. Gross return to family labour (US$ man-day^{-1}) is presented in Table 3. Family labour was the main source of labour for crop production in both terraced and un-terraced fields. Increased production and cropping intensity need additional labour per unit area per year. Barley, teff and maize production on terraced fields had an average gross return to family labour of US$ 2.32, 1.01 and 0.74 man-day^{-1}, respectively; while the respective values without terracing were US$ 0.44, 0.27 and 0.16 man-day^{-1}. This means that terraces provided higher gross return to family labour and thus, increased the incomes of rural farm households. Barley on terraced fields had the highest gross return to labour, i.e. US$ 2.3 man-day^{-1}.

The gross return to family labour from terraced fields was higher than the opportunity cost of labour in the study area. Assuming an income of US$ 1 day^{-1} as the threshold for poverty line, terracing can help the rural poor to move out of the poverty line. Generally, terraces brought higher return to family labour than the un-terraced areas. They create job opportunities and improve rural incomes and thereby improve rural livelihoods. However, terracing

Table 3
Gross and marginal return to family labour ($ man-day^{-1}) as affected by terraced and un-terraced fields.

Crop/catchments	Teff		Barley		Maize	
	Terraced	Un-terraced	Terraced	Un-terraced	Terraced	Un-terraced
Gross return ($ man-day^{-1})						
Upper	1.09	0.16	2.66	0.85	0.77	0.59
Middle	0.96	0.34	2.28	0.46	0.73	0.02
Lower	1.00	0.33	2.03	0.03	0.73	−0.13
Average	1.01	0.27	2.32	0.44	0.74	0.16
Crop/catchments	Terraced versus un-terraced		Terraced versus un-terraced		Terraced versus un-terraced	
Marginal rate of return (MRR) ($ man-day^{-1})						
Upper	7.95		7.3		1.2	
Middle	3.7		4.5		1.5	
Lower	5.3		4.9		−87.6	
Average	5.6		5.6		−28.3	

Table 4
Water productivity of major crops at Anjenie Watershed as affected by terraced and un-terraced fields.

Crops/systems	Total rainfall (mm rainfall growing season^{-1})	Water productivity		Water productivity at 25% run-off	
		kg mm^{-1}	\$ mm^{-1}	kg mm^{-1}	\$ mm^{-1}
Teff					
Terraced	933	1.01	0.31	1.35	0.42
Un-terraced	933	0.52	0.15	0.70	0.20
Barley					
Terraced	1358[a]	1.35	0.28	1.80	0.37
Un-terraced	731[a]	0.86	0.13	1.11	0.18
Maize					
Terraced	1445	1.21	0.17	1.61	0.22
Un-terraced	1445	0.56	0.07	0.74	0.1

[a] The difference in precipitation is because double cropping of barley is practiced in terraced field and thus stayed longer in the field and received more rainfall than barley grown on un-terraced field where barley is only harvested in the main cropping season thus received only rainfall of some months.

requires more family labour which is a limitation to vulnerable and elderly farmers.

The average marginal returns to family labour (Table 3) had positive values for teff and barley, being US$ 5.60 and 5.56 man-day^{-1}, respectively. Meanwhile, marginal returns on family labour was negative for maize (US$ −28.3 man-day^{-1}). This implies that an additional labour requirement for teff and barley production on terraced fields had generated additional revenue. But in the case of maize, additional labour was retrogressive. The rate of marginal return to family labour, meaning shifting from non-terracing practices to terraced farming practices was accompanied by positive returns for many of the studied crops. Generally, gross and marginal returns to family labour for terraces brought in a higher return compared to non-terraced; and this indicated that investment in terracing improved incomes.

3.5. Scope in improving water productivity

Crop water productivity is calculated as crop yield or its monetary values divided by the amount of water utilized during the vegetation period. According to Kassam and Smith (2001) at FAO, crop water productivity is defined as "Crop yield/Water consumptively used in ET". It may be quantified in terms of wet or dry yield, nutritional value or economic return. According to Molden (1997), water productivity is defined as "the physical mass of production or the economic value of production measured against gross inflows, net inflow, depleted water, process depleted water or available water." Therefore, crop water productivity in this study was calculated based on the total rainfall and effective rainfall by considering only runoff amount in the area and expressed in terms of kilo gram (kg) grain or US $ per millimetre (mm) water consumed. The average long-term amount of total rainfall in the area, 1690 mm yr^{-1} and the estimated run-off coefficient of 25% were the bases for the calculation. The length of the growing period of teff, barley and maize was also considered in calculating the values presented in Table 4. In this study, it was obtained that terraces improved water productivity of the three crops by at least 100% against un-terraced plots, which clearly shows the advantage of terracing in terms of efficient use of rainwater. Terraced barley had the highest water productivity in terms of grain yield per mm of water consumed (1.35 kg mm^{-1}) followed by maize (1.21 kg mm^{-1}) and teff (1.01 kg mm^{-1}). On the contrary, the calculated monetary values (economic water productivity) showed that barley and teff were almost similar (US$ 0.28 and 0.31 mm^{-1}, respectively); and this may a factor associated with the fact that both teff and barley take just 3 months in the field, while maize (US$ 0.17 mm^{-1}) was the least economically efficient crop, as it takes up more water.

3.6. Returns on investment

The parameters considered in this analysis were NPV and FIRR on investment (Table 5). Although terraces remain for a long time after construction, a lifespan of 50 years was chosen for this calculation. The initial investment cost of terracing was equivalent to US$ 46.51 ha^{-1} in the first year of construction, requiring about US$ 48.8 ha^{-1} to maintain in the first three years. Using a discount rate of 10%, the average NPV of investment in terraces for barley production over a time period of 50 years was US$ 1542. Across the catchment, the NPVs were found to be positive, indicating that terraces were financially viable. Investment in terracing is feasible and financially promising (positive NPV). Moreover, the FIRR was calculated and found to be 302% (average of the three catchments). This figure is higher than the discounted factor at 10%, indicating again the financial viability of terracing. The findings of this study are different from those obtained by Bekele and Holden (1998) and Kappel (1996) who showed that, except for low-cost technologies like grass strips, returns to soil conservation investments were too low, especially when the rate of discount may be high and subsidy was suggested as an incentive for adoption of SWC practices. De Graaff (2005) found negative NPV values for bench terraces in Peru when crop yield data were actually measured and profitability was lower than farmers' estimation.

3.7. Social, environmental and economic sustainability

The introduction of soil and water conservation activities in Anjenie watershed in 1984 did not adopt the food-for-work compensation system which was popular at the time. Instead, farmers worked voluntarily and were rewarded with the construction of a health centre by the project. This approach was successful in instilling a sense of ownership and responsibility among the community. As a result, the soil conservation structures and the clinic still exist and are functional after 25 years. The maintained terraces have developed into level benches in many places since their stabilized. The maintenance and management of the terraces have

Table 5
Net present value, financial internal rate of return and return on investment as affected by terraced and un-terraced fields.

Performance parameters	Barley (main crop on the study area)			
	Upper	Middle	Lower	Average
Discount factor	10%	10%	10%	10%
Discounted costs (US$ ha^{-1})	1616.2	2106.8	2011	1911.3
Discounted benefits (US$ ha^{-1})	3114.3	3880.6	3366	3453.6
NPV (50)	1498	1773.8	1355	1542.3
FIRR	291%	356%	258%	301.6%
ROI	108%	95.1%	77.7%	93.6%

been the full responsibility of the farmers and these activities were carried out well and on time. Two decades ago, the Anjene catchment was highly eroded and farmers could not produce enough food and thus the community was highly food insecure, a situation that caused regular out-migration of inhabitants to other areas in search of food in times of even minor droughts. The introduction of terraces improved crop production thereby reducing seasonal migration of farmers. Fodder became available and improved animal production. Moreover, farmers around Anjenie have started to grow maize crop in the area. Maize was not grown in the watershed previously due to water stress. But terracing has improved moisture conservation and hence crop diversity in the area. Farmers pointed out that during the first five years, there were problems of oxen ploughing due to the narrow spacing between the terraces. As a result, modifications of bunds (removal of alternate bunds) ensured wider terrace spacing suitable for oxen to plough. Soil and water conservation practices have been widely adopted over the years, with many farmers constructing terraces on their own initiatives beyond the Anjenie catchment. Terracing also reduces the risk of crop failure during dry spells in the rainy season, due to the water conserving effect (De Graaff, 2005). The economic sustainability of terraces could vary across agro-ecological zones as crop productivity, prices and opportunity cost of labour vary and thus, are site-specific. Better security in land tenure could help to improve commitment by farmers to conserve the soil in the area as has been seen elsewhere (Tenge et al., 2004).

4. Conclusions

This study confirmed that soil and water conservation has had long-term benefits to smallholder farmers especially in the Anjenie catchment in producing teff, barley and maize. Terracing was attributed to increased crop yields, with percent increases of 93%, 203% and 125%, respectively, as compared to crops grown in the same area but without terrace. This implies that investment in soil and water conservation increases crop production and land productivity. The results of the study also indicated that teff, barley and maize grown on terraced plots enabled farmers to earn net profit of US$ 20.9, 185.2 and −34.5 ha^{-1}, respectively. On the other hand, crop grown without terrace had negative net returns of US$ −112, −41, and −100.8 ha^{-1} for teff, barley and maize, respectively, a factor associated with high costs of inputs and labour demands. Moreover, barley, teff and maize with terrace had an average gross return to family labour of US$ 2.33, 1.01 and 0.74 $man\text{-}day^{-1}$, respectively; which accounts for five folds higher than the unterraced fields. Water productivity of the different crops was also 100% higher than without terrace intervention. With the average NPV of US$ 1542 and FIRR of 302%, investment in terracing was financially viable. Generally, it was found that terracing had contributed to food security, and household income, thereby impacting on poverty reduction. Construction of soil conservation structures often has high initial costs and long payback periods and thus could reduce household incomes in the short-term. But in the long term, the benefits far outweigh the costs.

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