

## Bio-Physical and Socio-Economic Impact of Integrated Watershed Management in Ojoje, Doyogena District Southern Ethiopia

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### Abstract

This study was conducted in Ojoje watershed of southern Ethiopia with the objective of evaluating biophysical and socio-economic impact of soil and water conservation (SWC) technological options in crop-livestock mixed farming systems. Three watersheds were assessed using formal interview and focus group discussions using stratified sampling procedure. The before and after intervention effects was assessed using t-test. The results indicated that land use improved from 68% before intervention to 88% after intervention. 91.3% of the participants perceived that land degradation was a serious problem before while the percentage decreased to 30.5% after interventions. 93.5% of the participants perceived that soil fertility decreased crop yield. There was 6% stone bund, 39% soil bund and 9% fanya-Juu before intervention but after intervention soil band increased to 80%, fanya-Juu to 12.5% and infiltration pits to 3.6%. Improved soil and water conservation (SWC) structures and live barriers have contributed for the reduced soil degradation. 88.7% of the sources of SWC structures such as stabilizers were from governmental organization. Soil bunds were covered with 92.3% grasses and 3.8% without any stabilizer. The results indicated that using live soil stabilizers improved soil fertility, reduced soil degradation and improved crop yield, implying soil and water conservation is crucial for improving soil fertility and overall crop productivity other than changing the microenvironment.

**Keywords:** Crop yield, Soil bunds; soil erosion; Stabilizers; soil and water conservation

### Introduction

Soil erosion is one of the major threats to agricultural production in Ethiopia. It is estimated that about 1.5 billion tons of soil eroded, with estimated 1-2 billion US \$ per year. Particularly, in steeply slope areas of the country, the rate of erosion is usually high and reaches as high as 300 tons per hectare per annum. Out of 60 million hectares of estimated agriculturally productive lands, 27 million hectares are highly eroded, 14 million hectares are severely eroded and 2 million hectares reached to irreversible erosion level (Meshesha and Birhanu, 2015). Soil erosion-induced land degradation and drought are major causes of food insecurity widely experienced in rural population. In highland rural areas, about 50% of land is categorized as degraded (Hakan & Hobson, 2013).

In Ethiopia, watershed management had been initiated in the 1970s at pilot level to tackle high rainfall related soil erosion which leads to serious soil degradation and its consequences in agricultural economy (Wolka, 2015). However, planning large watersheds comprised 30-40 thousand hectares had been started after ten years in 1980's. The initial purpose was mainly focused on implementing natural resource conservation using various soil conservation technology options. The efforts done at large scale remained unsatisfactory due to lack of active community participation due to less ownership and sense of responsibility over common resources on improvements made, and sustainable management of conserved structures which were implemented through public campaign work (MoARD, 2005). However, the impact of watershed management was not similar across watersheds because it was not exhaustively evaluated in representative and sufficient number of micro-watersheds from the perspective of changes in livelihood and food security (Wolka, 2015; Palanisamia and Kumarb, 2009).

Soil erosion is the main form of land degradation, caused by biophysical characteristics and human influences on environment. Recognizing land degradation as major environmental and socio-economic problems, the environmental policy of Ethiopia emphasized the need for preventing land degradation and making several interventions in different regions of the country. Effective integrated watershed management is one of the methods or approaches that could reduce these effects. Endorsing watershed development as strategy of agricultural development, the South Nation Nationalities Peoples Region (SNNPR) has launched the program since 2010.

Ojoje watershed is one of the areas found in central southern Ethiopia, Doyogena district, where community had been seriously affected by land topography and associated soil degradation problems. The watershed management development activity was conducted in the district from 2010 to 2014 for five years. Physical and biological soil and water conservation measures, soil fertility improvement practices, agro-forestry practices, introduction of different technologies, and community mobilization are some of the activities implemented in Ojoje watershed management program. Impact was assessed through comparison of situation or watershed status

at the beginning of interventions and after five years of interventions (MoARD, 2005). The objective of this study was to assess impacts of integrated watershed management and generating information's for future development and contributes decision making idea for policy makers that may indicate future direction towards sustainable natural resource management.

## Methodology

### Study site description

Doyogena district is located in Kembata-Tembaro Zone, Southern Nations, Nationalities and Peoples Region (SNNPRs) of Ethiopia. It is predominately highland agro-ecological zone, with an altitude ranges 1900-2800 meters above seas level (m.a.s.l.) and longitude and latitude of 7<sup>o</sup> North and 37<sup>o</sup> East, respectively. Ojoje watershed of Doyogena district is located at altitude between 2300–2650 m.a.s.l. suited at 260 km from Addis Ababa in South West via Alemgena Hossana, and at 171 km in North West of Hawassa the regional town of SNNPRs.

The area has a favorable rainfall pattern for agriculture, with an average annual rainfall of 1400 mm with bimodal distribution. Farmers' livelihood is based on mixed agriculture (crop cultivation and animal rearing). Major crops cultivated in the area are *enset* (*Ensete verticosum cheesman L.*), potato, wheat, barley, faba bean, field pea, head cabbage, carrot, beet root, and recently apple fruit tree. In the lower part of the district, farmers also cultivate sugar cane, *tef* (*Teff eragrostis*), and to small extent maize (either for animal feed or green maize for human).

The top layer of the soil in the areas is black clay loam, rich in organic matter while the sub-soil covers one meter depth, which is red clay loam. Human population of the district is 47,747 male, 49,880 female and total 97,627 with average landholding of  $\leq 0.25$  hectare per household (CSA 2016). The pressure exerted on the land has become more and more acute in the absence of adequate soil conservation measures due to the steepness of the slope of the areas (5-65%), soil fertility has severely been affected by erosion. Animal herding is also challenged by the scarcity of grazing lands and fodder.

### Participants' selection

The watershed area covers 386 hectares delineated from the three neighborhood bordering kebele's (Wagebeta heba, Ancha sedicho, and Gomora gawada) for intervention following watershed principles (guidelines) using GPS. Site selection was made purposively based on the severity of land degradation and land feature (slopes steepness) in the area. Representative farmers were selected from the watershed community using stratified and systematic random sampling techniques. Sampled farmers were stratified based on slope of the watershed but finally the overall impact was pooled together. Focus group discussions were made using pre-tested questionnaires.

### Data analysis

Data collected from the impact assessment was analyzed using SPSS soft ware (version 16) for statistical analysis. A pair-wise comparison was made before intervention with after intervention and finally differences among means were separated using Tukey's test at  $P < 0.5$ .

## Results and discussion

### Land use and management practices

Soil and water conservation and land improvement increases land cover for land rehabilitation. However, in the current study land use improvement did not show significant differences in five years but the trend of land use improved from 68% before intervention to 88% after project intervention (**Table1**). It could be due to positive impact of land improvement on moisture retention, reduced soil erosion, change in land-use pattern (Palanisamia and Suresh Kumarb, 2009). Out of 100% respondents, 91.3% perceived that land degradation was a serious problem before interventions while the percentage decreased to 30.5% after interventions, which was statistically significant at  $P < 0.01$ . The severity level of land degradation was also significantly decreased when compared before and after intervention. Highly sever 56.5% before to 22% after project intervention implied that interventions decreased ( $P < 0.05$ ) the severity level of land degradation (Table1). Using improved soil and water conservation (SWC) practices increased from 28% before to 48% after interventions in the area whereas traditional practices decreased from 63.2% before to 48.2% after interventions. This shows that shifting from traditional SWC practices to improved can significantly ( $P < 0.1$ ) improve SWC.

The occurrences of the most common hazardous events due to soil erosion in the study area were reduced significantly (Table 1). For example: peoples migration 2.3% to 0%; abandoning of farming lands from 20% to 10%, and washing of fertilizers and seeds from 43% to 31% before to after respectively. The occurrence of hazardous events to human, house, materials and migration of peoples in the study area has significantly decreased at ( $P < 0.05$ ); on the other hand biological SWC structure stabilizers increased the availability animal

feed. This findings agree with the impacts of watershed program is on the structural changes in the activities. It is perceived that more importance given to the land based activities; there will be increased area under cultivation, reduction in the migration status, improvement in the livestock status and other rural non-farm activities (Study report on watershed development, 2001).

**Table1** Land use management, land degradation and hazardous events occurrence

Features	Project Intervention				P value	
	Before		After			
	N	Column %	N	Column %		
Improvement on land use for last 5 Years	Yes	26	68.4%	53	88.3%	NS
	No	12	31.6%	7	11.7%	
Any form of plantation/ vegetation	Yes	4	7.3%	34	57.6%	
	No	51	92.7%	25	42.4%	
Land degradation occurrence	Yes	42	91.3%	18	30.5%	39***
	No	4	8.7%	41	69.5%	
Severity level of land degradation	High	26	56.5%	5	21.7%	15.89**
	Medium	15	32.6%	7	30.4%	
	Low	2	4.3%	9	39.1%	
	None	3	6.5%	2	8.7%	
Hazardous events (damage) caused due to erosion in the area	To house	5	11.4%	0	0.0%	18.65**
	To materials	3	6.8%	6	12.5%	
	Migration	1	2.3%	0	0.0%	
	To human	2	4.5%	1	2.1%	
	Abandoning farming lands	9	20.5%	5	10.4%	
	Washing of fertilizers	19	43.2%	15	31.3%	
	None	5	11.4%	21	43.8%	
Common type of SWC practices	Traditional	36	63.2%	27	48.2%	5.38*
	Improved	16	28.1%	27	48.2%	
	Both	0	0.0%	0	0.0%	
	Not at all	5	8.8%	2	3.6%	

NS, not significant, \*\*\* =  $P < 0.01$ ; \*\* =  $P < 0.05$ ; \* =  $P < 0.1$

### Soil and water conservation measures

Physical and biological SWC measures are commonly practiced in most part of the country. As well some physical and biological SWC structures were adapted in the study area. The adaptation of structures has shown improvement before and after intervention. Thus it was 6% stone bund, 39% soil bund, 9% *fanya-Juu*, and 3% none SWC before intervention; but after project intervention 80% soil bund, 12.5% *fanya-Juu*, 3.6% infiltration pits (Table1). The result reveals that integrated watershed development intervention improved the existing SWC measures with a significant difference at ( $P < 0.01$ ) for example soil bund from 39-80% (Table 2).

Community participation on construction of SWC structures increased from 13.5% to 80.4%, inversely individual farmers (households heads) participation has decreased from 62.2% to 8.9% and this indicates that the awareness of community is increasing in the importance and ownership on SWC structures. The trend of SWC structures construction increased by 20.7% from before to after project interventions. Implementing of integrated watershed development has significantly improved community participation on construction of SWC structures and existence of improved SWC structures at ( $P < 0.01$ ) (Table 2). Experiences on SWC structures maintenance has increased from 64.9% to 76.8% by household before and after project intervention which is significantly different at ( $P < 0.1$ ).

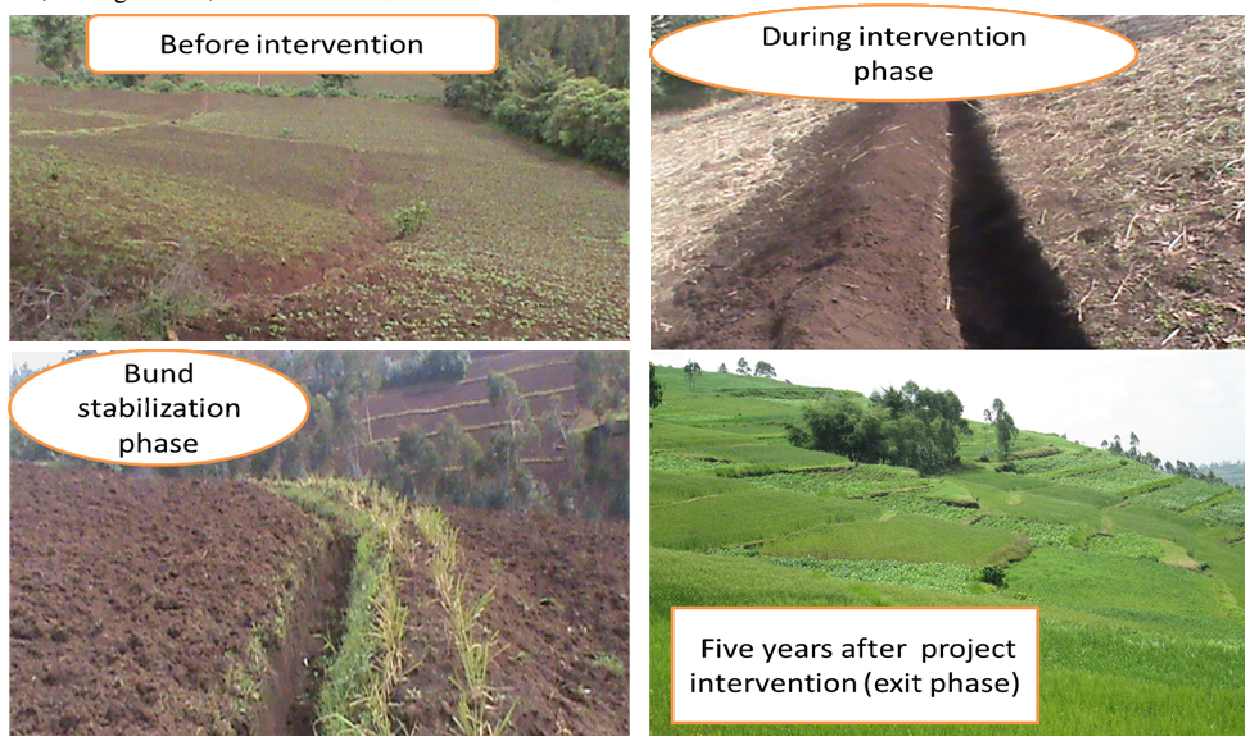
Time for SWC structures construction was 62.2% and 92.9% construct after crop harvesting & till next cultivation season before and after intervention respectively. Stabilization of physical SWC structures is done during rainy season. This result showed that there is significant difference in the time of SWC structures construction in the study area at ( $P < 0.05$ ), which is assumed as an appropriate time for SWC practices (Table 2). This result agrees with findings of (Water & Land Resource Centre, 2015) implementing physical conservation measures during dry season and biological conservation measures at the beginning of rainy season is best for stability of physical SWC structures.

A physical land feature of the watershed was changed, soil loss was minimized, crop performance, and livestock feed sources were improved after project intervention, (Fig-1) shows a relative changes observed in the watershed.

**Table 2** Soil and water conservation practices

Criteria	Project Intervention				P value	
	Before		After			
	n	Column N %	n	Column N %		
Type of improved SWC practices in the area	Stone bund	2	6.1%	0	0.0%	26.41***
	Soil bund	13	39.4%	45	80.4%	
	Fanya-juu	3	9.1%	7	12.5%	
	Trenches	0	0.0%	0	0.0%	
	Infiltration pits	1	3.0%	2	3.6%	
	None	14	42.4%	2	3.6%	
The SWC done in the area	Government	0	0.0%	0	0.0%	50.24***
	Safety net	0	0.0%	3	5.4%	
	Community	5	13.5%	45	80.4%	
	Household	23	62.2%	5	8.9%	
	Others	0	0.0%	1	1.8%	
	No improved SWC	9	24.3%	2	3.6%	
Maintenance of SWC structures done by	Government	0	0.0%	1	1.8%	11.69*
	Safety net	0	0.0%	0	0.0%	
	Community	4	10.8%	10	17.9%	
	Household	24	64.9%	43	76.8%	
	Others	0	0.0%	0	0.0%	
	No improved swc	9	24.3%	2	3.6%	
Time to construct SWC structures	After crop harvesting & till next cultivation season	23	62.2%	52	92.9%	15.68**
	Together with crops	2	5.4%	2	3.6%	
	Whenever needed	2	5.4%	1	1.8%	
	No Improved SWC	10	27.0%	1	1.8%	

NS, not significant, \*\*\* =  $P < 0.01$ ; \*\* =  $P < 0.05$ ; \* =  $P < 0.1$



**Figure 1** Physical and biological soil and water conservation from initial to exit phases

**Status of soil fertility**

Ojoje watershed community perception about the effect of soil erosion on food security was 81.3% believes



decreasing of soil fertility decreases crop yield & leads to poverty, 15.6% believes it causes damages on crops, soli & thereby bring poverty and 3.1% demolishes all crops sown with the fertilizer. After intervention 93.5% perceived decreasing of soil fertility decreases crop yield & leads poverty and 6.5% it causes damages on crops, soli & thereby bring poverty. These result shows significant difference in the level of community perception about the effect of soil erosion on food security ( $P < 0.01$ ).

Out of 100% respondents of community about the occurrence of soil nutrients depletion before project intervention 100% respondents perceived that there is soil nutrients depletion. But five years after project intervention out of 100% respondents 32.7% perceived still there was soil nutrients depletion problem. This result shows that the level of soil nutrient depletion is decreasing significantly after intervention ( $P < 0.01$ ). The first cause for soil nutrient depletion in the study area was 89.3% and 29.4% due to soil erosion before and after intervention respectively. This result shows significant differences on the first cause that leads to high soil nutrient depletion before and after intervention at ( $P < 0.05$ ). The second cause perceived for soil fertility depletion; 46.4% intensive cultivation, and 52.9% absence of fallow before and after project intervention respectively. Community perception in ranking of soil fertility depleting causes before and after project intervention showed significant difference at ( $P < 0.05$ ). The opinion of the community shows the cause of soil nutrient depletion before project intervention 89.3% believes soil erosion as first cause. Five years after intervention community perception 29.4% soil erosion as first cause. This result implies that the. Intervention of the integrated watershed development project minimized soil loss problem and as result soil depletion was decreasing. In other way soil nutrient depletion is not only due to soil erosion but also other factors such as intensive cultivation, and absence of land fallow are significantly causing soil nutrient depletion in the study area. In other cases low inorganic and organic fertilizer application as well as absence of crop rotation does not show significant difference as causes on soil fertility depletion before and after.

**Table 3** Soil fertility and nutrient depletion related issues

Criteria	Project Intervention				P value	
	Before		After			
	N	N %	N	N %		
Farmers perception	Yes	36	100%	18	32.7%	40.81***
occurrence of soil nutrients depletion	No	0	0%	37	67.3%	
If yes	It causes damages on crops, soil & thereby bring poverty	5	15.6%	3	6.5%	3.28***
	Diminishes all crops sown on lands with low fertility	1	3.1%	0	0.0%	
If yes first cause of nutrient depletion	Intensive cultivation	1	3.6%	1	5.9%	18.77**
	Low inorganic fertilizer application	0	0%	3	17.6%	
	Absence of fallow	1	3.6%	3	17.6%	
	Low organic fertilizer application	1	3.6%	3	17.6%	
	Absence of crop rotation	0	0.0%	2	11.8%	
	Soil erosion	25	89.3%	5	29.4%	
If yes second cause of nutrient depletion	Intensive cultivation	13	46.4%	2	11.8%	19.26**
	Low inorganic fertilizer application	5	17.9%	3	17.6%	
	Absence of fallow	1	3.6%	9	52.9%	
	Low organic fertilizer application	7	25.0%	1	5.9%	
	Absence of crop rotation	2	7.1%	1	5.9%	
	Soil erosion	0	0%	1	5.9%	

NS, not significant, \*\*\* =  $P < 0.01$ ; \*\* =  $P < 0.05$ ; \* =  $P < 0.1$

Wheat crop performance before and after IWM intervention on the same field below (Fig 2) showed a significant yield difference. Before IWM intervention was 2000 kg/ha and after intervention it was raised to 6200 kg/ha with area specific fertilizer recommendations. The experiments conducted to determine fertilizer rate for wheat at Ojoje watershed revealed that 200 kg Dap and 150 kg Urea fertilizer application gives the highest yield when compared with blanket recommendation of 100 kg DAP and 100kg Urea. The result obtained in this experiment was due integrated effect of soil water conservation practices and soil fertility management practices.

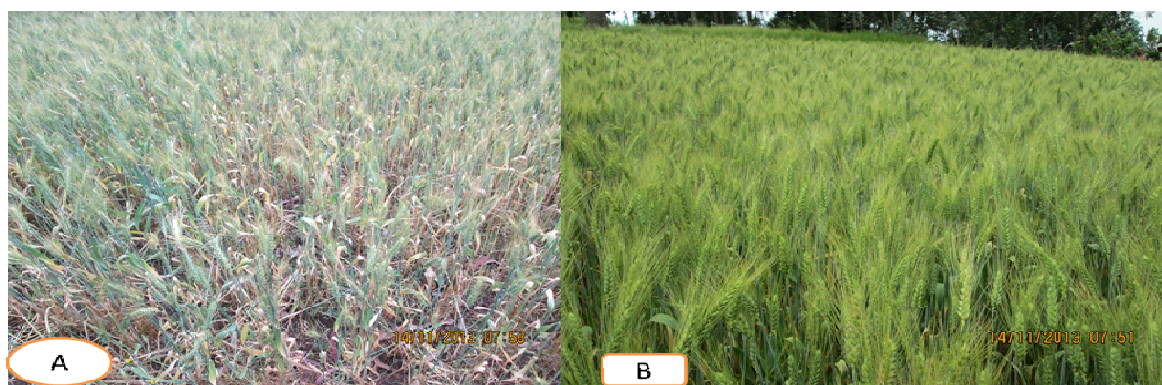


Fig 2. Wheat crop performance before and after IWM intervention on the same field (with blanket recommendation (A) and with area specific fertilizer recommendation rate (B) picture by A.Abate

### Community mobilization

Community mobilization in the watershed activities before was 68.1% perceived no mobilization and after intervention 3.6% respondents perceived no mobilization. After project intervention 63.6% respondents perceived they are mobilized two times in a week. Community participation can be judged in terms of giving time to the project and contribution in cash/or kind towards works, both on development and management of private and common property resources (Palanisamia and Suresh Kumarb, 2009). Sources of SWC structures stabilizers, 64.5% no source, to 88.7% from government (Areka ARC) before and after intervention respectively. The use of biological barriers for physical structures stabilization and maintenance was 19.3% before project intervention; while after interventions is 89.1% ( $P < 0.01$ ). The type of bund stabilizers used in the watershed before interventions were; 25.8% grasses, 3.2% bushes, 6.5% both (grasses and bushes), and 64.5% no stabilizer; but after interventions 92.3% grasses, 3.8% both and 3.8% no stabilizer. The preference of bund stabilizers increased significantly 25.8% before and 95.8% after is grasses. The reason for the preference after technological interventions 80.4% was dual purpose (bund stabilizer & feed). Soil conservation versus livestock feed generation is the immediate outcomes of integrated watershed management. These all the results statically showed highly significant differences at level of ( $P < 0.01$ ).

**Table 4** The status of community mobilization and bund stabilization for the last five years

Criteria	Project Intervention	Before		After		P value
		N	N%	N	N%	
		Community mobilization for SWC	Three times a week	1	2.1%	
2 times a week	12	25.5%	35	63.6%		
One time a week	2	4.3%	4	7.3%		
Not any	32	68.1%	2	3.6%		
Trend of bund stabilizers use	Yes	11	19.3%	49	89.1%	54.82***
	No	46	80.7%	6	10.9%	
If yes, type of stabilizers	Grasses	8	25.8%	48	92.3%	41.65***
	Bushes	1	3.2%	0	0.0%	
	Both	2	6.5%	2	3.8%	
	None	20	64.5%	2	3.8%	
Sources of bund stabilizers	Government	6	19.4%	47	88.7%	45.98***
	Market	0	0.0%	1	1.9%	
	Neighbors	4	12.9%	3	5.7%	
	No stabilizer	20	64.5%	2	3.8%	
Preference of stabilizers	No answer	1	3.2%	0	0.0%	42.79***
	Grasses	8	25.8%	46	95.8%	
	No stabilizer use	1	3.2%	0	0.0%	
	No answer	20	64.5%	2	4.2%	
	Others	2	6.5%	0	0.0%	
The reason for preference	High vegetative performance	3	30.0%	0	0.0%	23.98***
	No answer	2	20.0%	1	2.2%	
	Cattle feeding	2	20.0%	4	8.7%	
	Dual purpose (bund stabilizer & feed)	1	10.0%	4	8.7%	
		2	20.0%	37	80.4%	

NS, not significant, \*\*\* =  $P < 0.01$ ; \*\* =  $P < 0.05$ ; \* =  $P < 0.1$

### Main causes of soil erosion

There are different factors governing the occurrence of soil erosion in the study area, as out of 100% respondents ranked that; 1<sup>st</sup> cause is heavy rainfall (39.1% and 37.3%); 2<sup>nd</sup> cause is absence of fallow (42.9% and 13.6%); 3<sup>rd</sup> cause is cultivation of steep slopes (33.3% & 33.9%); and 4<sup>th</sup> cause is overgrazing (62.5% & 20.3%) perceived before and after project intervention. The community perception revealed that a heavy rain fall and steep slope cultivation does not show significant difference. The absence of land fallow and overgrazing showed a significant difference in causing effect soil erosion at ( $P < 0.05$ ) due to intensive cultivation. In general the causes of soil erosion ranked in its decreasing order were; 1<sup>st</sup> heavy rain fall; 2<sup>nd</sup> absence of land fallow (due to intensive cultivation); 3<sup>rd</sup> cultivation of steep slope, and 4<sup>th</sup> overgrazing.

**Table 5** Farmers perception on major causes of soil erosion in its decreasing order

No	Cause of soil erosion	Before Project Intervention			After Project Intervention			P value
		Count	N %	Rank	Count	N %	Rank	
1	Heavy rainfall	9	39.1%	1 <sup>st</sup>	22	37.3%	1 <sup>st</sup>	NS
2	Steeply slop cultivation	7	30.4%	2 <sup>nd</sup>	13	22.0%	3 <sup>rd</sup>	
3	Absence of fallow	2	8.7%	4 <sup>th</sup>	4	6.8%	4 <sup>th</sup>	
4	Deforestation	5	21.7%	3 <sup>rd</sup>	17	28.8%	2 <sup>nd</sup>	
5	Overgrazing	0	0.0%	5 <sup>th</sup>	2	3.4%	5 <sup>th</sup>	
6	Lack of sense of ownership	0	0.0%	6 <sup>th</sup>	1	1.7%	6 <sup>th</sup>	

NS, not significant, \*\*\* =  $P < 0.01$ ; \*\* =  $P < 0.05$ ; \* =  $P < 0.1$

### Changes perceived on soil properties after five years of interventions

Based on a diversified criteria and knowledge, farmers evaluated the fertility of soil in their own land in the catchments. Conventionally, farmers in the study area categorize their land in to three fertility status namely: high, medium and poor. The soil fertility level falls medium in all those of three kebel's (Wagaeta, Anchsedich and Gomora). The soil color of study area (Wagabeta 57.6%, Anchsedich 73.3% and Gomora 100.0%) mostly tends to black soil. As respondents perceived workability of the soils are; 21.2% Difficult, 30.3% Average and 48.5% Easy in Wagaeta heba; 33.3% average and 66.7% easy in Ancha sedicho and Gomora 100% easy. Depth of the soil at Wagabeta 33.3% Deep, 48.5% Medium and 18.2% Shallow at Ancha sedicho 60.0% Deep and 40.0% Medium and at Gomora case 100% deep. Infiltration rate of the soil falls in medium level in case of Wagebata and Ancha sedicho but it falls 100% high in case of Gomora. The trend of soil fertility was increasing in the last five years significantly in all kebel's.

**Table 6** Soil characteristics and fertility status in the last five years (after intervention)

Features		Kebele					
		Wagabeta		Ancha sedicho		Gomura	
		Count	N %	Count	N %	Count	N %
Level of soil fertility	Poor	4	10.0%	1	6.3%	0	0.0%
	Medium	31	77.5%	11	68.8%	3	75.0%
Soil color	High	5	12.5%	4	25.0%	1	25.0%
	Red	7	21.2%	3	20.0%	0	0.0%
	Black	19	57.6%	11	73.3%	1	100.0%
	Gray	7	21.2%	1	6.7%	0	0.0%
	White	0	0.0%	0	0.0%	0	0.0%
Workability of soil	Difficult	7	21.2%	0	0.0%	0	0.0%
	Average	10	30.3%	5	33.3%	0	0.0%
	Easy	16	48.5%	10	66.7%	1	100.0%
Depth of soil	Deep	11	33.3%	9	60.0%	1	100.0%
	Medium	16	48.5%	6	40.0%	0	0.0%
	Shallow	6	18.2%	0	0.0%	0	0.0%
Infiltration rate of soil	Poor	8	25.0%	0	0.0%	0	0.0%
	Medium	21	65.6%	11	78.6%	0	0.0%
	High	3	9.4%	3	21.4%	1	100.0%
Trend of soil fertility	Increasing	36	90.0%	11	68.8%	3	75.0%
	Decreasing	3	7.5%	1	6.3%	0	0.0%
	No change	1	2.5%	4	25.0%	1	25.0%

### Conclusion

Improved soil and water conservation (SWC) structures and live barriers have contributed for the reduced soil degradation. 88.7% of the sources of SWC structures such as stabilizers were from governmental organization.

Soil bunds were covered with 92.3% grasses and 3.8% without any stabilizer. The results indicated that using live soil stabilizers improved soil fertility, reduced soil degradation and improved crop yield, implying soil and water conservation is crucial for improving soil fertility and overall crop productivity other than changing the microenvironment.

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