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Technical viability of physical soil and water conservation structures implemented in Lake Hawassa watershed, southern Ethiopia.

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Physical soil and water conservation measures with ultimate intention of reducing sever soil erosion and its associated impact had been implemented for the last four decades in southern Ethiopia. Yet, so far the technical viability of the implemented structures weren't studied. Therefore, the objective of this study was to evaluate the technical viability of the implemented physical soil and water conservation measures and its management, maintenance and appropriateness in communal and private lands of the upper catchments of Lake Hawassa watershed. The data was collected by field observation and direct measurement of the implemented structures. Moreover, focused group discussion and key informant interview was done. Descriptive statistics was used for data analysis. The results were compared with standards. The collected data were presented in Table and Figures. The study result showed that Level soil bund and Check dam were implemented in communal land by public participation, while Level soil bunds and Fanya- juu were found in private land. The implemented structures were appropriate for the catchment, while the layouts of most implemented structures were not as the standard. The regular maintenance and management practices were also minimal. As the result, technically deficient SWC measures were found as cause of soil erosion and witnessed that construction of SWC structure in field is not an end means by itself for effective controlling of soil erosion. To be effective the implemented SWC structures has to be appropriate for the area and technically be sound. Regular maintenance and management of the structure after implementation is also vital to achieve its very inception objective.

Key words: Check dam, Level Fanya- juu, soil bund, standards.

INTRODUCTION

Soil properties which affect the plant growth are a complex combination of physical, chemical and biological processes (Coleman et al., 1983; Bargali et al., 1993; Joshi et al., 1997). Soil degradation in last few decades have been increased tremendously and adversely affected the productivity at global scale (Bargali et al., 2018; Padalia et al., 2018). It is prevalent at a tragic rate in Ethiopia. Land degradation, comprising degradation of

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ABBREVIATIONS: SNNPR, Southern Nations and Nationalities Regional State; **SWC,** Soil and Water Conservation natural vegetation, soil erosion, loss of soil fertility and moisture stress is a well-known problem in Ethiopia (Herweg and Stillhardt, 1999). It was estimated that about 1.5 billion tons of soil which has the monetary value of US$1 to 2 billion per year is being eroded every year. The rate of erosion in highlands of the country is extreme and reaches up to 300 tons per hectare annually (FAO, 1984; Hurni, 1988; Hawando, 1997). Out of 60 million hectares of estimated agriculturally productive land, 27 million hectares are significantly eroded, 14 million hectares are seriously eroded and 2 million hectares reached at the point which is irreversible (FAO, 1984). Land degradation, particularly by water erosion, is a major threat to food security, environmental sustainability and prospects for rural development in Ethiopia (Bishaw, 2001).

To minimize the negative impacts of soil erosion, both local communities and government has been using their tremendous efforts towards soil and water conservation (Wolancho, 2015). A traditional soil conservation practices and agronomic measures had been practiced in various parts of the country including terracing of Konso people (Lundgren, 1993; Osman and Severborn, 2001). The government's efforts towards soil conservation were started during the 1970’s (Hurni, 1986; Desta et al., 2005). Since then, a huge amount of money has been invested in an attempt to introduce soil and water conservation measures particularly in the areas where the problem of soil erosion is threatening and food deficit is widespread (Desta et al., 2005). However, due its large scale planning units which range 30 to 40 thousands of hectares and absence of local community participation the projects were ended with unsatisfactory results during the first two decades of its commencement (Desta et al., 2005; Habtamu, 2011).

In the early 1980’s, the Ethiopia government with the aid from international government or non-government organization had actively involved in soil and water conservation programs. A package of soil and water conservation measure was developed through constructing terraces, bunds, tree planting and closure of grazing areas (Elias, 2005).During this period, from 1976 up to 1988, food for work programs founded the construction of 800,000 km of soil and stone bunds on cultivated land, 600,000 km of hill side terraces were built, and 80, 000 hectares were closured for regeneration. As the government realized the problem of land degradation, it took policy action. In this regard a forestation and wildlife conservation and development policy was declared in 1980. From 1991 to 2001, following the policy the government initiated various studies and capacity building program and massive soil and water conservation interventions that focused on the cultivated lands. The capacity building program involved training of professionals at the national level and farmers on the local. In this regard, soil and water conservation was included in the university curriculum and the mandate to train farmers was given to the ministry of agriculture and rural development (Bekele and Holder, 1999).

Starting from 2005, watershed management projects focuses on the wise use of natural resources such as land, water and vegetation in given watershed to obtain an optimum level of production with the minimum level of ecological degradation (Desta et al., 2005). To achieve this end, since 2010, the movement on watershed management campaign is going on throughout the country (Wolancho, 2015; Meshesha and Birhanu, 2015). Besides to the efforts made by several NGOs, the campaign on soil and water conservation program which was initiated by FDRE government for the last one a decade has offered a positive contribution in watershed development and management for the country (Meshesha and Birhanu, 2015). On the other hands, stakeholders are debating about the negative impacts of SWC structures on the farm land.This stakeholders argue that the structures were aggravating erosion, rather than meeting its very objective. It is known that the success of implemented soil and water conservation structure is the function of several factors including environmental, economic, social, institutional and technical aspects. Among many other factors, to be effective the implemented structure should be technically sound. The technical viability of soil and water conservation is useful to determine whether the structures are working successfully or not. Therefore, the ultimate purpose of this study is to evaluate the technical viability of physical soil and water conservation structures implemented in the upper catchment of Lake Hawassa watershed. It is hypothesized that the SWC structures implemented in the upper catchments of Lake Hawassa watershed fit the standards and appropriate for the area. In this catchment, physical SWC structures were implemented both on communal and private lands.

MATERIALS AND METHODS

Description of the study area

The study area, Lake Hawassa watershed, is located within the central rift valley of Ethiopia and it has 1455 Km^2 area (Kebede et al., 2014). The upper catchment of Lake Hawassa watershed is partially found in central rift valley region. The Catchment has is geographically situated between 38°37'E to 38°42'E and 7°02'N to 7°07'N. It covers an area with a wide altitudinal range of 1680 to 2940 m above sea level. The mean annual rainfall of the catchment is 1306.78 mm and bimodal rainfall pattern (Kebede et al., 2014).

Methodology

At the beginning, reconnaissance survey was implemented to select representative areas of the upper lake Hawassa watershed, through the help of the developmental agent and local elders found in the study area. Accordingly, two potential communal and private lands with different soil and water conservation physical structures

Table 1. Standard values for physical soil and water structure layouts.

Layout	Level Fanya-juu Slope <15%	Level soil bund Slope <15%	Gabion check dam Slope >15%
Length*	10	10	10
Top width*	0.5	0.5	0.5
Bottom width*	0.5	0.5	0.5
Depth*	0.5	0.5	0.5
Embankment height*	0.5	0.5	0.5
Embankment top width*	0.3	0.3	0.3
Embankment bottom width*	1.6	1.6	1.6
Tie ridge*	0.5	0.5	0.5
Berm length*	0.25	0.25	0.25
Vertical interval*	1	1.5	1.5
Alignment (degree)	0	0	0

* indicates the units on measurement is in Meter
Source: Hurni (1986) and Desta et al. (2005).

Figure 1. Soil and water conservation structure under construction.
Source: Yericho Berhanu.

were selected purposively and a total of 80 hectares of land, 40 from private and 40 from public were delineated as an experimental unit. Systematic sampling techniques were used to measures the layouts of the structure. The data was collected through measuring the layouts of already implemented physical SWC structures in the area. Based on this, total of 172 physical SWC structure layouts were measured. The layout measurement was done on the implemented structures length, depth, top width, bottom width, embankment height, embankment top width, embankment bottom width, length of tie ridge, berm length, vertical interval and alignment were measured. Moreover, Focused group discussion and key informants interview was done. The appropriates of implemented SWC structures was determined through considering the guidelines provided by Hurni (1986) and Lakew et al. (2005). Moreover, the expert's judgment (appropriate or not) was also taken in to account. The observed layouts of implemented structures were compared with the standards stated in Tabe 1 through using descriptive statistics and t-tests with SPSS 20. Moreover, frequency analysis was conducted for the appropriateness, management and maintenances of the implemented physical SWC structures.

RESULTS AND DISCUSSIONS

Physical soil and water conservation structures implemented in the study area.

Several physical conservation measures with the purpose of reducing surface runoff thereby increasing infiltration were implemented through public participation in the study area (Figure1).

Table 2. Physical SWC structures Implemented in the Upper Lake Hawassa watershed.

Types of structure	Land ownership					
	Private		Public		Private and Public	
	Frequency	%	Frequency	%	Frequency	%
Level soil bund	60	61.9	60	80	120	69.8
Level fanya-juu	37	38.1	0	0	37	21.5
Gabion check dam	0	0	15	20	15	8.7
Total (n)	97	100	75	100	172	100

Table 3. Observed responses on approporateness, management and maintenance of implemented SWC structures in Hawssa wateshed.

Ownership	Physical SWC structure	Measured parameter	Response	
			Yes (%)	No (%)
Private	Level soil bund	Appropriateness	100	0
		Management	20.34	79.66
		Maintenance	20.34	79.66
	Fanya-Juu	Appropriateness	100	0
		Management	21.62	78.38
		Maintenance	21.62	78.38
Communal	Level soil bund	Appropriateness	100	0
		Management	13.3	86.7
		Maintenance	96.7	3.3
	Gabion Check dam	Appropriateness	96.7	3.3
		Management	93.3	6.7
		Maintenance	0	100

Level soil bund and Level Fanya-juu were constructed in the middle and lower parts of the watershed, while Gabion check dam constructed in the gullies of the upper hillsides catchment of the watershed.

The great majority of implemented structures were Level soil bund followed by Level fanya juu and Gabion check dam (Table 2). Level Fanya juu were implemented only in private land where as Gabion check dam is in public land. This result has similar indication with the previous study of Meshesha and Birhanu (2015) in which the aforementioned physical SWC structures were commonly used in the south western parts of Ethiopia. Similar study criticized the diversity SWC in Ethiopia in general and southern Ethiopia in particularly poor. Surprisingly the SNNP region has diverse agro-climatic condition, while it is known that the types of SWC structure implemented in the region was determined and fixed from the center without considering the local agro-ecology and climatic condition. Similar study in south western Ethiopia assures that no one structure is recommended for the entire syndrome in the region, while it has to be condition/site specific.

Appropriateness, management and maintenance of implemented stuctures in the catchment

The result indicated in Table 3 shows the percent of different physical soil and water conservation according to their management, maintenance and appropriateness in the study area.

The result presented in Table 3 shows that considering the local agro-ecology and shallow soil depth stated in Hurni (1986) and Desta et al. (2005), those structures constructed in the area (both in private and public land) were appropriate for the catchment. On the other hands management and maintenance of the implemented structure in the private land is very minimal (Table 3, Figure 2).

This result is in line with findings of Wolancho (2015), in which it he found that lack of regular maintenance is the challenge for campaign works of SWC in southern Ethiopia. In the contrast with private ownership, Management of the structure at public land is very high. This result, contradict with findings of Wolancho (2015). The Key informants stated that because of annual

Figure 2. Weak management and maintenance practice (Cattle heard over and destroying the structure).

national campaign program, the structures in the public land were subjected for regular maintenance via public participation. In opposite, with this, the responsibility of maintaining structures at private land were the mandate of the owner and they were less interested for its maintenance.

Fitness of the layout of implemented structures with standards in communal and private lands in the study area.

The comparison result of the implemented physical SWC structures layout with its test values shows that there were significant differences between the soil conservation dimensions (measured variables) with its design standards (Table 4). All measured parameters, except top embankment width, in the private land were not as the standard. Similarly, in communal land there is a significant difference between the observed result and the standards in most parameters. Except few dimensions, the majority of physical SWC structures both at private and public land were not constructed according to the standard. This indicates that the implemented physical SWC structures were not technically viable.

The result presented in Table 4 shows that the length of all physical soil and water conservation structures, were significantly less than the standards. Similarly, the majority of layouts have negative mean difference and the variation was statistically significant (Table 4). Key informants mentioned that labor cost and lack interest to construct structure in their farm land were the main reason for poor construction of the structures. Similarly, focused group discussion result shows that farmers were forced to construct physical SWC structures both at public and private land, and conclude that the lack of agreement and poor interest were the reason for the structure layouts to fail to meet its design standard. The positive mean difference of vertical interval presented in Table 4 also verify that the structures are constructed far apart beyond the standard, and it indicates that less number of structures are designed to construct at a given parcel of land. This could be probably to save labor cost or lack of understanding about the importance of soil and water conservation structures. According to Meshesha and Birhanu (2015), lack of skill and interest were two main reasons for the constructed structure to fail to meets the standard. Moreover, both key informant interview and focused group discussion also support this finding. One of the key informant stated as follows: “*We are forced to construct the structure, both in our own land and public land, without our interest for the sake of Local Government interest’’.* Hence, it is understood that awareness creation and reaching a consensus before commissioning the structure is important for effective intervention.

Conclusion

Physical soil and water conservation structures had been implemented in Ethiopia for last five decades through public participation. The intervention was targeted to reduce severe soil erosion from farm land and associated ill effects land degradation. Moreover, it was focused to maintain soil fertility and improve agricultural productivity. To this end, a lots of effort has been done to conserve soil at private and communal lands, while the success has found to been less comparable with the effort done so far. In spite of having its large area coverage, the contribution/effects of the intervention were criticized by citizens. Most stakeholders argue that implemented structures were the source of severe soil erosion, rather than achieving its initial intentional objective. Moreover,

Table 4. Comparison of physical SWC layouts with standards under both land ownership categories.

Land Ownership	Types of SWC structure	Variable	n	DF	Mean	MD	Test value	t-cal	P-value
Private	Level soil bund	Length	60	59	9.44	-0.56	10	-5.68	0.001
		Top width	60	59	0.46	-0.04	0.5	-3.656	0.001
		Bottom Width	60	59	0.46	-0.04	0.5	-3.656	0.001
		Depth	60	59	0.4	-0.1	0.5	-7.364	0.001
		Embankment height	60	59	0.33	-0.17	0.5	-7.157	0.001
		Length of tie ridge	60	59	0.41	-0.09	0.5	-6.276	0.001
		Embankment top width	60	59	0.32	+0.02	0.3	1.57	NS
		Embankment bottom width	60	59	0.8	-0.8	1.6	-39.88	0.001
		Berm length	60	59	0.37	-0.63	1	-33.89	0.001
		Slope	60	59	9%	-	-	<15%	-
		Soil depth	60	59	0.9	-	-	-	-
		Vertical interval	60	59	1.91	+0.41	1.5	7.65	0.001
	Fanya-Juu	Length	37	36	9.42	-0.58	10	-4.49	0.001
		Top width	37	36	0.45	-0.05	0.5	-2.754	0.009
		Bottom Width	37	36	0.45	-0.05	0.5	-2.754	0.009
		Depth	37	36	0.41	-0.1	0.5	-5.491	0.001
		Embankment height	37	36	0.32	-0.18	0.5	-5.728	0.001
		Length of tie ridge	37	36	0.42	-0.08	0.5	-4.803	0.001
		Embankment top width	37	36	0.33	0.03	0.3	1.43	NS
		Embankment bottom width	37	36	0.81	-0.79	1.6	-30.11	0.001
		Berm length	37	36	0.38	-0.62	1	-25.77	0.001
		Slope	37	36	9%	-	-	<15%	NS
		Soil depth	37	36	0.9	-	-	-	-
		Vertical interval	37	36	1.86	+0.36	1.5	5.3	0.001
Communal	Level soil bund	Length	60	59	7.66	-2.34	10	-7.41	0.001
		Top width	60	59	0.69	+0.19	0.5	10.45	0.007
		Bottom Width	60	59	0.54	+0.04	0.5	2.79	0.001
		Depth	60	59	0.42	-0.09	0.5	-8.08	0.001
		Embankment height	60	59	0.13	-0.37	0.5	-27.89	0.001
		Length of tie ridge	60	59	0.73	+0.23	0.5	2.731	0.008
		Embankment top width	60	59	0.72	+0.42	0.3	6.42	0.001
		Embankment bottom width	60	59	0.91	-0.7	1.6	-9.55	0.001
		Berm length	60	59	0.12	-0.88	1	-53.21	0.001
		Vertical interval	60	59	1.05	-0.45	1.5	-8.9	0.001
	Gabion Check dam	Length	15	14	7.87	-2.13	10	-2.61	0.021
		Top width	15	14	0.56	+0.06	0.5	1.67	NS
		Bottom Width	15	14	0.56	+0.06	0.5	1.67	NS
		Depth	15	14	0.43	-0.07	0.5	-3.56	0.003
		Embankment height	15	14	-	-	0.5	-	-
		Length of tie ridge	15	14	0.11	-0.39	-	-4.11	0.001
		Embankment top width	15	14	-	-	-	-	-
		Embankment bottom width	15	14	-	-	-	-	-
		Berm length	15	14	-	-	1	-	-
		Vertical interval	15	14	1.57	+0.07	1.5	2.22	0.044

Note: (MD is Mean Difference, NS is not significant) this study found that the layout of the implemented structures were not as the standards and fail to fit the design requirements. The practice of regular maintenance and management were also minimal. Due to this reason, until recent soil erosion significantly affects the agricultural sector and threat to the economic development of Ethiopia. Hence, it was assured that simply constructing physical soil and water conservation structure on farm land is not an end means by itself to conserve soil and water, while it has to be as the standard and regular maintenance and management has to be in the place. Otherwise, the end result is beyond the expected.

RECOMMENDATION

Based on the findings of this study, the following recommendations are forwarded:

It is important to enhance farmers' awareness on the importance of soil and water conservation structures since most farmers belief that implementation of structure is minimizing their land area for cultivation.

Capacity building for development agents is also important since poor design alignment of implemented structures were associated with the skills gaps.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This research was done through considering professional ethics and authors are responsibility for any competing interest for participation.

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CONFLICT OF INTERESTS

The author has not declared any conflict of interest.

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