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Assessment of community based watershed management practices: emphasis on technical fitness of physical structures and its effect on soil properties in Lemo district, Southern Ethiopia

Amanuel Bekele[1], Abebayehu Aticho[2*] and Endalkachew Kissi[2]

Abstract

Background: Soil erosion is one of the major causes for food insecurity, and environmental degradation in Ethiopia. To reduce erosion effects, soil and water conservation practices have been promoted at farm level and watershed scale-executed via mass-community mobilization program. In Lemo district, little information is available on suitability of soil conservation practices implemented through this program. The aim of this study was to assess technical fitness of physical soil conservation structures implemented via mass-community mobilization, its effect on soil properties, and extent of farmers participation in soil conservation practices. Field observation and physical structure component measurments were used to assess the technical fitness. Whereas, composite soil samples were collected from steep, moderate and gentle slope classes to evaluate the effects of conservation practices on soil properties. Structured questionnaire was used to assess the farmers participation in soil conservation.

Results: As compared to nationally established specification of graded soil bund for areas similar with Lemo district, technical errors were found in bund spacing and vertical interval. The studied soil properties were not significantly ($P > .05$) influenced with sample distance from soil bund. But, soil moisture content, bulk density, clay, reaction, electrical conductivity, organic carbon, total nitrogen and cation exchange capacity were significantly ($P < .05$) affected with slope gradient. These properties become better as the slope gradient decrease. Among the study household heads, only 59.69% were participated in soil conservation activities. Land holding size, cropland slope, contacts with extension agents and training opportunity were significantly ($P < .05$) contributes for farmers' participation in soil conservation activities.

Conclusions: To ensure the sustainability of watershed management practices and minimize observed technical faults on conservation structures continued technical supports, trainings, and follow-ups are required in the study area.

Keywords: Soil erosion, Physical structure, Watershed management, Community based watershed management, Soil conservation, Soil and water conservation

*Correspondence: j.aticho@yahoo.com
[2] Department of Natural Resource Management, College of Agriculture and Veterinary Medicine, Jimma University, Jimma, Ethiopia
Full list of author information is available at the end of the article

Background

The global agricultural production and productivity has been challenged with soil erosion related problems. Almost all lands in Sub-Sahara Africa (SSA) are prone to soil degradation, and Ethiopia is among the most affected countries (Vlek et al. 2008). Every year, about 10 million hectare (ha) of croplands are abandoned globally (Pimentel 2006) and 6.5 million ha in Africa (Mekonen and Tesfahunegn 2011). Due to erosion, about 12 tons (ha/year) of soils in lost every year in Ethiopia, and the economic impacts of this loss is estimated about $139 million-which is 3–4% of agricultural growth domestic product (GDP) of the country (Demelash and Stahr 2010). Erosion affects soil physical conditions (e.g., reducing soil depth, water-holding capacity), and chemical properties (e.g., nutrient depletion) that affect agricultural production (Hurni et al. 2010). In addition, soil erosion causes negative effect on environment, agronomic productivity, food security and the overall life quality (Atnafe et al. (2015).

In 1970s, soil and water conservation program was incited in Ethiopia with the support international organizations to reduce soil degradation, improve agricultural production, enhance food security and reduce poverty (Gashaw et al. 2014). The focus of this program is construction of physical structure such as terraces and stone bunds (Alemu and Kidane 2014). Recently, nationwide soil and water conservation campaigns (mass-community program) are promoted to ensure sustainable watershed development, food security and socioeconomic development (Meshesha and Birhanu 2015). Most of the conservation practices introduced via this campaign are able to reduce soil erosion in highlands of Ethiopia; for example soil bund reduce erosion by 30.5%, improve infiltration, reduce surface runoff and soil loss, improve basic soil conditions (pH, CEC, OC etc.), and increases crop yields (Ayalew 2011; Wolka et al. 2011; Adimassu et al. 2013; Sinore et al. 2018).

However, soil and water conservation technologies are not equally successful or effective in many parts of Ethiopia. Level of farmers participation in soil conservation activities are influenced by inadequate expert follow-up and assistance, farmers landholding size and technical skills (Wolka and Negash 2014; Mekonen and Tesfahunegn 2011; Sinore et al. 2018). Nowadays, millions hectare of lands are covered with soil and water conservation practices. But, successful stories are reported from northern Ethiopia and scientific evidences that justify the success of soil conservation technology in southern Ethiopia including of Lemo district are limited. The information on suitability of soil and water conservation measures implemented in Lemo district will assist the stakeholders (farmers, development agents, decision makers) in the selection, design and proper implementation of conservation measures for better outcomes. Therefore, the objectives of present study were to assess; (1) technical fitness of physical soil and water conservation structures implemented in the study area, (2) effect of the implemented structures on selected soil physicochemical properties, and (3) factors affect levels of farmers participation in soil conservation practices.

Methods

Description of the study area

The study area-Lemo district is located in Hadiya Zone, Southern Nation Nationalities and People's Regional State (SNNPRS), Ethiopia (Fig. 1). The district is located in south of Addis Ababa the capital of Ethiopia and near to Hossana town—the administrative centre of Hadiya zone. The district is 232 km away from Addis Ababa and 15 km from Hossana. Geographically, Lemo is situated between 7°22′00″–7°45′00″N latitude and 37°40′00″–38°00′00″E longitude.

The study area has 1–7% flat to gentle slope, 7–15% moderate slope, and 15–30% steep slope. The coverage of flat to gentle slope 54.3%, moderate slope 5.4%, and steep slope 40% (LWARDO 2009). Lands at different slope classes are used for crop production—both annual and perennial (85.96%), grazing (4.24%), natural and plantation forests (6.2%), and unproductive land covers 3.6%. The mean annual rainfall varies from location to locations, and ranges from900 - 1400 mm (MOARD 2005), whereas the minimum and maximum temperatures are 13 and 23 °C, respectively. The dominate soil types of the area is nitisol and vertisol (FAO 2006).

According to CSA (2007), total population of Lemo district is 118,594 composed of 58,666 male and 59,928 female. Regarding place of settlement, 1.73% of the population lives in semi-urban and the rest in rural area. Subsistence mixed agriculture (crop and livestock) is the major livelihood basis of rural settlers. Fully, nature dependent subsistence agriculture is exercised for centuries, and land degradation is becomes one of major constraint for agricultural production and productivity. Currently, soil and water conservation structures implemented by mass-community mobilization program and individual farmers initiative are become popular solution to minimize the impacts of land degradations.

Methods of data collection

Direct field observations and measurements of physical soil and water conservation structures (graded soil bunds) implemented via mass-community mobilization campaigns were used to assessed technical fitness of conservation practices in the study area. The observations and measurements were made on nine separate fields

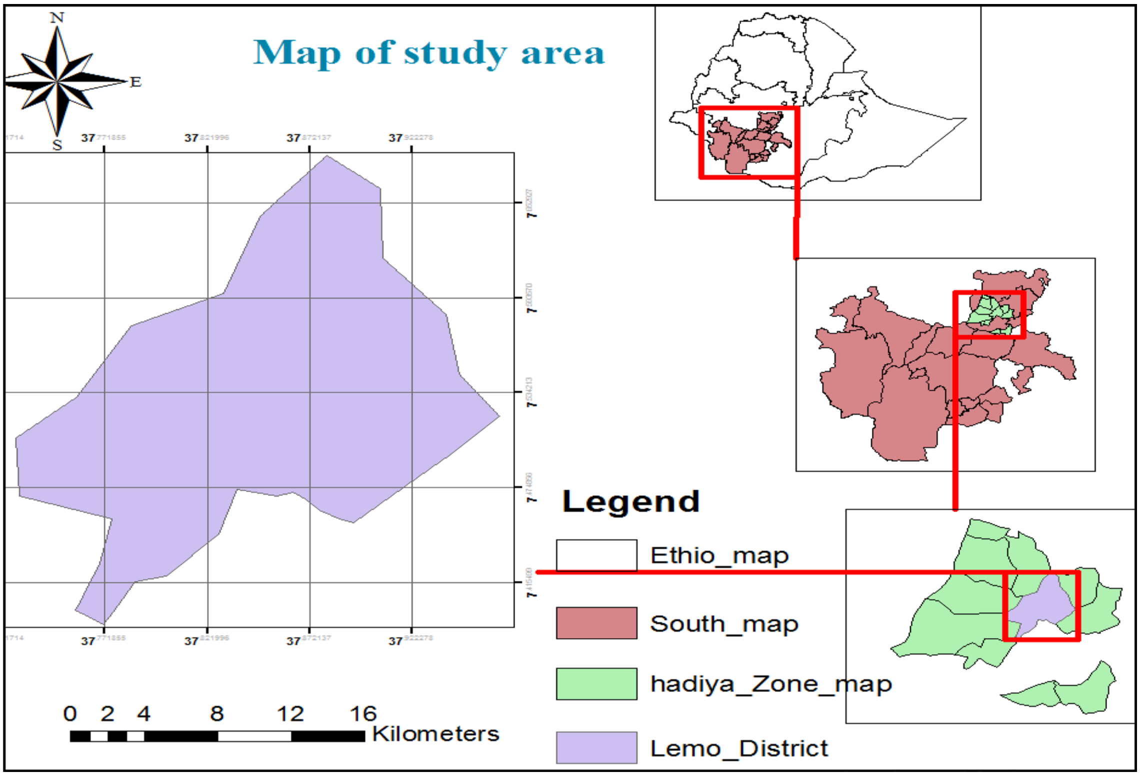

Fig. 1 Map shows the location of Lemo district in Southern Nations Nationalities and People's Regional State, Ethiopia

Table 1 Nationally recommended specifications of graded soil bunds for areas similar to Lemo district

Bund components	Recommended standards	Sources
Embankment height (m)	.5–.75	FEPA (2004)
Embankment top width (m)	.3–.5	SAONREPA (2004)
Embankment bottom width (m)	1–1.5	FEPA (2004)
Berm length (m)	.2–.25	SAONREPA (2004)
Ditch width (m)	.5–.6	SAONREPA (2004)
Ditch depth (m)	.5–.6	SAONREPA (2004)

situated at gentle, moderate, and steep slope classes. The field measurement of soil bunds embankment height, embankment top width, embankment bottom width, ditch depth, ditch size, berm length, vertical interval, and space between bunds were carried out using tape meter, water level, string (rope) and graduated poles. The measured bund components were compared against nationally established specifications based on soil texture, slope and agro-ecological zones (Table 1) to identify limitations of the implemented soil and water conservation structures.

The composite soil samples were collected from croplands situated at moderate, steep and gentle slopes treated with soil bund through mass-community mobilization program. The soil samples were collected from 1, 2, and 4 m away from soil bunds using auger at 0–15 cm sampling depth. Total of 27 composite samples were collected for laboratory analysis (3 slope classes * 3 sampling intervals * 3 replications). In addition, undisturbed core samples were collected to determine soil bulk density and moisture content.

A structured questionnaire was used to assess factors affect the levels of farmers participation in soil and water conservation practices in Lemo district. The questionnaire was administered to representative household heads found in the three slope positions (steep, moderate steep and gentle). The respondent household sample size was determined using Cochran's (1977) formula with marginal error of 5% and confidence interval of 95%. Accordingly, 129 respondent household heads were selected for questionnaire survey. A proportional sampling technique was employed to decide the numbers of respondent household from each slope class (Table 2). Lists of household heads recorded at Village (locally called Kebele) administrative office was used as sample frame for random selection of the households for face-to-face interview. Besides, focused group discussions (FGD) and key

Table 2 The distribution of sample population in the three slope classes in the study area

Slope class	Total population	Population proportion	Sample population
Moderate slope	510	(510/1897)*100	35
Steep slope	898	(898/1897)*100	61
Gentle slope	489	(489/1897)*100	33
Total	1897		129

informants (KI) interviews were used to triangulate and supplement the information acquired from household survey.

Soil laboratory analysis

All of the soil parameters were analysed at Soil Laboratory of College of Agriculture and Veterinary Medicine, Jimma University. The samples were air dried, grounded, and passed through 2 mm soil sieve mash for soil texture, reaction (pH), electrical conductivity (EC), organic carbon (OC%), total nitrogen (TN%), available phosphorous (Av.P ppm), and cation exchange capacity (CEC meq/100 g) analysis. Soil particle size distribution was determined using hydrometer method (Waling et al. 1989) in which hydrogen peroxide (H_2O_2) was used to destroy organic matter whereas, sodium hexametaphosphate $(NaPO_3)_6$ and sodium carbonate (Na_2CO_3) were used as dispersing agent. Bulk density was determined by core method, the ratio of solid mass to total volume of core sample after the soil dry in oven for 105 °C for 24 hrs (FAO 2007).

The soil reaction (pH-H_2O) was measured using pH meter method. The pH meter glass electrode was inserted in the suspension of 1:2.5 (soil: water on a mass to volume basis) after calibrating the pH meter with buffer solution of pH 4 and 7. Similarly, soil EC was measured using the glass electrode method within the suspension of a 1:2.5 (soil: water on a mass to volume basis) using EC meter. Total nitrogen was determined using Kjeldahl digestion—distillation and titration procedures (Bremmer 1996). Soil organic carbon (OC) was determined following Walkley and Black (1934) wet digestion and titration method whereas soil organic matter content was computed from OC. The soil available phosphorous (Av. P) was extracted using Bray-II method (Van Reeuwijk 1992) and P in the extract was measured via spectrophotometer at wavelength of 882 nm. Soil cation exchange capacity (CEC) was determined after leaching the soil sample with ammonium acetate method (1N NH_4OAc) at pH 7.0 (Waling et al. 1989).

Data analysis

The two-way factorial analysis of variance (ANOVA) was used to test the effects of slope and sample distance on basic soil property. The ANOVA was preformed following General Linear Model (GLM) procedure at probability (P) of .05 and confidence interval (CI) of 95%. After checking the assumptions of ANOVA, main and interaction effects of the independent variables (soil parameters) were analyzed using SPSS version 20 software (IBM Corp 2011). Normal distribution and confidence interval of soil dataset was tested using Shapiro–Wilk test; null hypothesis of the test was that, soil samples were normally distributed, and the test value was significant at 5% confidence interval (CI) the distribution will be non-normal. Finally, Chi square test was used to assess the effect of socio-economic and demographic factors on farmers participation in soil conservation practices.

Results and discussion

Technical fitness of physical soil and water conservation practices

Graded soil bund was the common soil and water conservation structure build at croplands situated in different slope classes; steep, moderate and gentle. Except space between successive bunds and vertical intervals, the rest components of bunds were compatible with the national specifications (Fig. 2). The space between successive bunds built on croplands at the three slope classes through mass-community mobilization program was meaningfully wider than the recommended standards. The interviews conducted with Focused Group Discussion (FGD) and key informant (KI) revealed, the main reasons for the presence of wider space between bunds were lack of sufficient technical support during bund design and layout, misunderstand on the importance space between bunds, and focus on quantity (i.e., area coverage with bund) rather than quality of the work. In addition, wider spaces between bunds were preferred by farmers to minimize possession of cultivable areas with physical structures. Unlikely, wider space between bund may cause the formation of rills and gullies in cropland and needs more labour for maintenance of bunds. Meshesha and Birhanu (2015) reported, the substandard physical structure are ineffective in controlling erosion and require immediate repairs. An inadequate technical support for farmers is reported as causes for ineffective soil and water conservation practices (Wolancho 2015).

When the space between soil and water conservation structures is wider than the required space, the risk of soil erosion on cropland will increase (Masresha 2014; Molla and Sisheber 2017). On top of this, the vertical interval of bunds in the study area was lower than national standard, this could facilitate surface run off and destruction

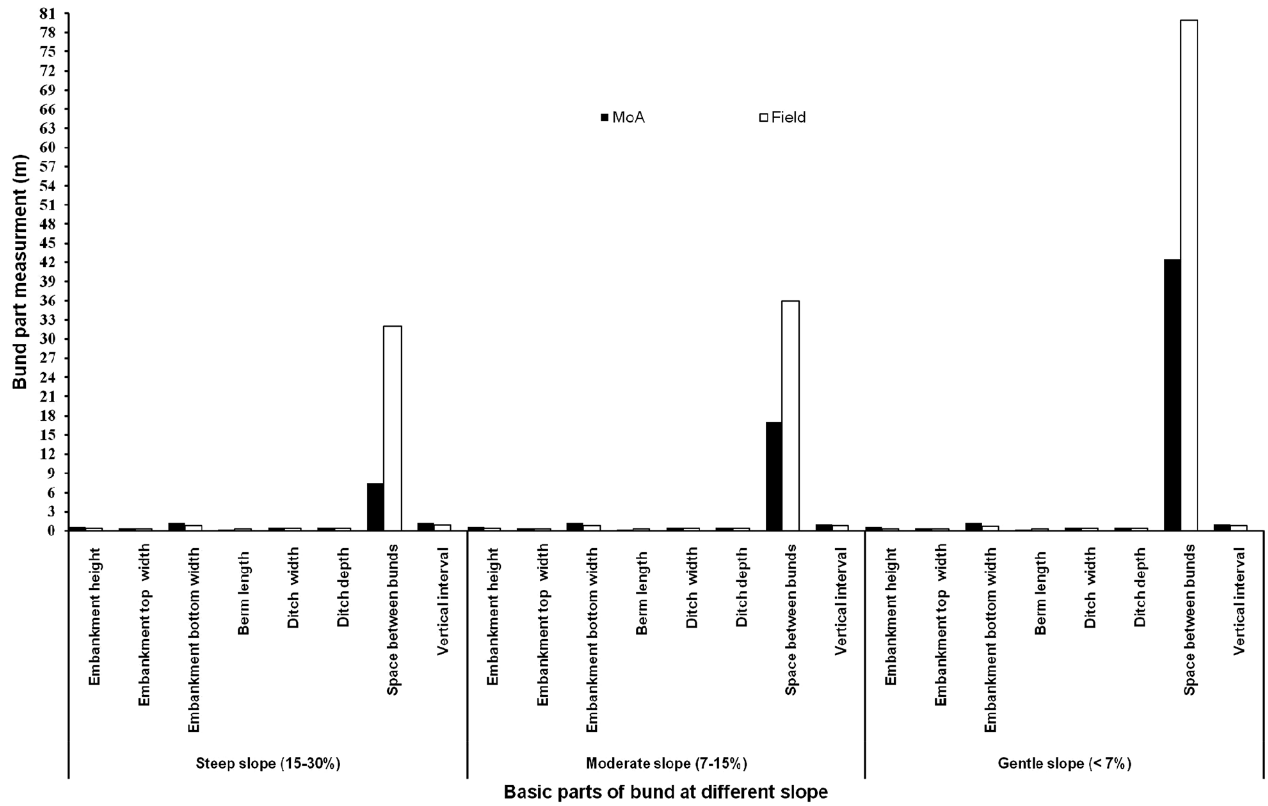

Fig. 2 Comparison of graded soil bunds constructed in Lemo district against standards established by the Ministry of Agriculture and Rural Development (MoA)

of bunds as well as croplands via allowing accumulation of water in the bunds. As rainwater accumulated inside the structures, soil erosion and runoff damage the constructed structures. This agrees with Molla and Sisheber (2017) who reported, when vertical interval of graded soil bund is lower than the required standard huge amount of runoff can be generated and cause damage to bund embankment and croplands.

Effects of graded soil bund on soil properties

The normal distribution test result presented in Table 3 revealed; the significant test values of the all soil parameters were greater than the chosen alpha level ($P > .05$). This indicates the soil samples were normally distributed among the slope classes and ability to represent the study area where the sample came. Thus, the null hypothesis that the soil samples came from a normally distributed population was accepted and alternative hypothesis was rejected. Shapiro–Wilk normality tests with *P* value greater that .05 shows normal distribution of the datasets (Ghasemi and Zahedias 2012).

The two-way factorial ANOVA test showed, the interaction effect of slope position and soil sample distance was not significantly ($P > .05$) affected soil particle size distribution, moisture content, bulk density, pH, EC, OC, TN, CEC and Av.P (Table 4). Similarly, soil-sampling distance from bunds was not significantly (> .05) affected the studied soil properties. However, slope position was significantly ($P < .05$) affected soil clay content in the study area (Table 4). A high clay proportion was observed at gentle slope and low at steep slope, as the slope gradient increases clay content declined.

The difference in clay proportion among slope positions could be due to the influence of topography (slope) and past erosion events that removed clay from steep slope and deposited at gentle slope area. Previous studies show, slope positions has meaningful effect on soil texture through its influence on soil formation and erosion processes (Selassie et al. 2015; Bezabih et al. 2016). Other finding also reported, soil and water conservation structures influence the processes of soil erosion and deposition at different slope position (Ademe et al. 2017).

As shown in Table 4, soil moisture content was significantly ($P < .05$) affected by slope positions. The soil moisture increases along the slope gradient; this is due the nature of water movement, low bulk density, clay content and soil organic matter content. Challa et al. (2016) reported, soil moisture increase at low bulk density and

Table 3 Soil sample distribution and confidence interval (CI) test

Soil parameters	Slope	Statistic	Df	Sig.	95% CI	
					Lowe limit	Upper limit
pH (H_2O)	Moderate	.536	9	.216	4.884	5.563
	Steep	.617	9	.701	4.951	5.724
	Gentle	.590	9	.360	4.813	5.612
AV.P (ppm)	Moderate	.956	9	.760	5.268	5.618
	Steep	.895	9	.226	5.173	5.764
	Gentle	.952	9	.709	5.474	5.753
OC (%)	Moderate	.955	9	.743	1.586	2.390
	Steep	.946	9	.641	2.301	2.777
	Gentle	.915	9	.353	2.857	3.566
OM (%)	Moderate	.844	9	.640	2.303	3.462
	Steep	.881	9	.159	3.640	4.534
	Gentle	.964	9	.838	5.498	6.315
TN (%)	Moderate	.964	9	.835	.125	.1892
	Steep	.863	9	.104	.152	.229
	Gentle	.883	9	.170	.231	.360
C:N (ratio)	Moderate	.563	9	.100	10.980	14.522
	Steep	.834	9	.501	11.164	17.103
	Gentle	.865	9	.107	9.146	13.909
CEC (meq/100 g)	Moderate	.976	9	.941	17.358	20.795
	Steep	.969	9	.890	17.906	22.465
	Gentle	.975	9	.936	24.552	29.145
EC (dS/m)	Moderate	.901	9	.256	.310	.398
	Steep	.665	9	.201	.279	.583
	Gentle	.873	9	.132	.599	.7687
Sand (%)	Moderate	.769	9	.109	23.12	28.22
	Steep	.930	9	.481	16.29	21.26
	Gentle	.891	9	.205	14.88	21.12
Clay (%)	Moderate	.920	9	.396	34.98	37.02
	Steep	.933	9	.510	38.34	43.66
	Gentle	.966	9	.856	55.62	66.38
Silt (%)	Moderate	.908	9	.301	17.41	23.93
	Steep	.893	9	.215	37.20	40.80
	Gentle	.958	9	.775	31.74	34.70
BD (g/cm^3)	Moderate	.988	9	.994	1.134	1.260
	Steep	.932	9	.497	1.015	1.147
	Gentle	.961	9	.811	.976	1.097
MC (%)	Moderate	.713	9	.302	24.934	26.655
	Steep	.826	9	.240	24.752	27.506
	Gentle	.938	9	.564	27.32	28.912

high soil organic matter content. Further, statistical analysis shown, soil bulk density was significant ($P < .05$) affected with slope position. The lowest bulk density was recorded at gentle slope (1.03 g cm^{-3}) and highest at steep slope (1.19 g cm^{-3}). The change in soil bulk density along slope position was attributed to soil organic carbon and clay fraction. This coincides with Hailu et al. (2012) who stated, bulk density raise with organic carbon, and accumulation of crop residues. Moreover, soil bulk density is directly related with slope position, as the slope increase bulk density also increased and vice versa (Bezabih et al. 2016).

Soil reaction was significantly ($P < .05$) affected with slope positions, high pH value was observed at gentle

Table 4 Main and interaction effects of slope and soil sample distance from bund on basic soil properties

Source of variations	SS	df	MS	F
Soil clay content (%)				
Slope	31.000	2	45.000	29.824***
Sample distance	34.889	2	47.444	23.007^{ns}
Slope * sample distance	23.111	4	30.778	19.951^{ns}
Soil MC (%)				
Slope	28.425	2	14.212	6.201**
Sample distance	2.288	2	1.144	.499^{ns}
Slope * sample distance	.680	4	.170	.074^{ns}
Soil BD (g/cm^3)				
Slope	.123	2	.061	9.354**
Sample distance	.008	2	.004	.625^{ns}
Slope * sample distance	.036	4	.009	1.362^{ns}
Soil pH				
Slope	3.185	2	1.593	10.750***
Sample distance	.519	2	.259	1.750^{ns}
Slope * sample distance	.370	4	.093	.625^{ns}
Soil EC (dS/m)				
Slope	.533	2	.266	15.384***
Sample distance	.026	2	.013	.765^{ns}
Slope * sample distance	.099	4	.025	1.426^{ns}
Soil OC (%)				
Slope	6.759	2	3.379	17.020***
Sample distance	.222	2	.111	.560^{ns}
Slope * sample distance	.856	4	.214	1.078^{ns}
Soil TN (%)				
Slope	.094	2	0047	11.299***
Sample distance	.004	2	.002	.501^{ns}
Slope * sample distance	.012	4	.003	.735^{ns}
Soil CEC (meq/100 g)				
Slope	31.120	2	59.060	26.502***
Sample distance	15.132	2	7.566	1.261^{ns}
Slope * sample distance	25.601	4	14.650	2.441^{ns}
Soil Av.P (ppm)				
Slope	.151	2	.076	.793^{ns}
Sample distance	.014	2	.007	.073^{ns}
Slope * sample distance	.130	4	.032	.340^{ns}

*** Significant at P-value < .001; ** significant at P-value < .05; *ns* non-significant at P-value > .05

slope and the lowest at moderate slope. The presence of highest soils pH at gentle slope was associated with high soil OC, CEC and clay fraction moved with runoff and erosion from steep slope positions. This corresponds with Yimer et al. (2006) who stated, surface runoff in steep slope decrease soluble basic cations, increase H^+ activity and reduced soil pH. Nevertheless, the current finding contradict with Yeshaneh (2015) who reported, the presence of lowest soil pH at gentle slope associated with removal of basic cations due to intensive and continues cultivation. Electrical conductivity (dS/m) was significantly ($P < .05$) changed with slope positions, relatively higher EC (.68 µs/cm) was found at gentle and lower (.35 µs/cm) at steep slope. This occurs due to removal of basic cations with erosion from steep slope and accumulation at gentle slope areas associated with high rainfall of the area. This is consistent with Bezabih et al. (2016); EC differs along slope position due to runoff and soil erosion processes that affects soil basic cations.

Soil organic carbon and total nitrogen were significantly ($P < .05$) influenced with slope positions, the highest amount was found at gentle slope and lowest at steep slope. This could be due to the removal of organic matter through erosion and surface runoff from steep slope and deposition in gentle slope, and presence of better soil moisture at gentle slope. Earlier study show, soil organic carbon content increases with moisture content and clay deposition at lower slope position (Hailu et al. 2012). Aytenew (2015) reported, soil nitrogen content decrease with increasing slope; the content is low at steep slopes and high at gentle slope position. In case of soil cation exchange capacity, significant ($P < .05$) difference was observed along slope positions, the highest amount was found at gentle slope and lowest at steep slope (Table 4). The highest CEC at gentle slope was associated with high soil clay and organic carbon content. Former studies show, high soil CEC at gentle slope is related with the deposition of clay minerals and organic matter into lower slope positions, and CEC decreases as clay and organic matter content of soil decrease (Aytenew 2015; Bekele et al. 2016).

Factors affect farmers participation in soil and water conservation practices

About 95.3% of the respondent household heads acknowledged the presence of soil erosion (in the forms of rill, sheet and gully) problem on their croplands whereas 4.7% did not recognized the problem (Fig. 3). Among the farmers' acknowledged the presence erosion problems on their cropland, 27.9% perceived the problem as severe on their cropland, 41% as moderate and 26.4% as minor. Farmers perception and understanding about the degree of erosion problem on their cropland govern their willingness and participation in soil and water conservation activities. This agrees with Tesfaye and Kasahun (2015) who reported, most farmers easily identify the problem of soil erosion in their cropland. Framers understanding on erosion problems determine their engagement in soil and water conservation practices (Gebre et al. 2013). Farmers who had better understanding of soil erosion problem would take conservation action earlier and invests more resources on conservation practices

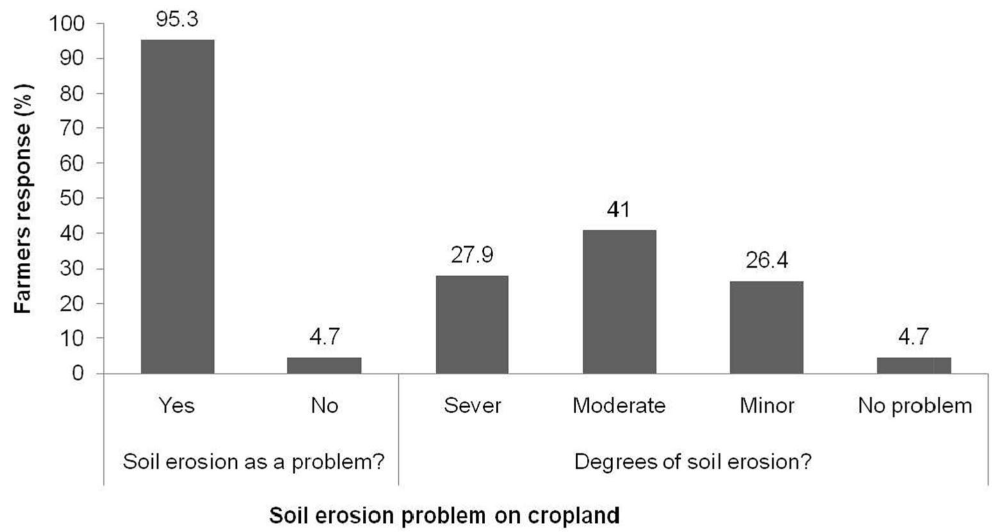

Fig. 3 Summery on farmers' perception of soil erosion problems on their cropland

to minimize the impacts of erosion on their cropland. In addition, interviews conducted with focus group discussion (FGD) and key informants (KI) revealed the spatial variability of soil erosion (moderate, sever and minor) due to topographic, livestock grazing pressure, soil conservation practice adoption, steep slope cultivation, and improper farming systems. Spatially, more soil erosion problems were reported from steep slope areas, farmers situated at the steep slope areas were more likely to participate in conservation practices than the others.

As presented in Table 5, 93.5% of farmers participated in soil and water conservation activities were 26–64 years old while 6.5% were over 64 years old. The chi-square test statistics indicated; household head age, educational level, family size, and cropland access means were not significantly ($P > .05$) influence farmers participation in soil and water conservation activities. Whereas, household land holding size, farmland slope, contact with development agents (extension workers), and access to conservation training were significantly ($P < .05$) influence the participation of farmers in soil and water conservation activities. The lowest landholding size in the study area was below .5 ha and the highest was above two ha; only 8% of farmers using soil and water conservation had above two ha cropland. This implies participations of farmers with relatively larger land holding size are better than the smaller size. Previous studies indicate, farmers having larger farm sizes are interest to implement conservation technologies in their cropland than the others (Gebre et al. 2013; Abebe and Sewnet 2014; Sinore et al. 2018).

Among farmers participated in soil and water conservation activities, 32% had croplands on moderate steep slope, 49% on steep slope, and 19% at gentle slope (Table 5). A slope situation of cropland determines farmers adoption of soil and water conservation technologies (Birhanu and Meseret 2013; Gebre and Weldemariam 2013). Atnafe et al. (2015) also reported as the slope gradient of cropland increases the probability of soil erosion risk increases and farmers use soil and water conservation practices.

Most of the farmers preformed soil and water conservation activity on their croplands had frequent contact with extension workers (DAs), and attends training provide by different stakeholder (e.g., NGO). Other studies indicated, contact with local extension workers, and access to training on soil conservation technologies improve farmers participation in soil conservation practices (Birhanu and Meseret 2013; Atnafe et al. 2015; Sinore et al. 2018). The knowledge and skills obtained from extension workers and training improve farmers decision and execution of soil and water conservation technologies (Getachew 2014).

Conclusions

Mass-community mobilization based physical soil and water conservation practices is one of the most important approaches used to address soil erosion and land degradation problems at national level. Most of the physical soil and water structures built through this program in Lemo district has technical problems on space between bunds and gradient of graded bund. These limitations are potential causes for soil conservation

Table 5 Factors affect farmers use of soil and water conservation practices (n = 129)

Variables	Category	Participant N (%)	Non-participant N (%)	X^2
Age (year)	26–64	72 (93.5)	40 (77)	13^{Ns}
	> 64	5 (6.5)	12 (23)	
Educational status	Illiterate	43 (56)	20 (38)	
	Able to read and write	19 (25)	24 (46)	14^{Ns}
	Elementary school	12 (15)	3 (6)	
	Secondary school	3 (4)	5 (10)	
Family size (number)	1–3	6 (8)	3 (6)	
	4–6	29 (38)	13 (25)	10.9^{Ns}
	7–9	35 (45)	28 (54)	
	≥ 10	7 (9)	8 (15)	
Land size (ha)	≤ .5	4 (5)	28 (54)	
	.6–1	23 (30)	10 (19)	
	1.1–1.5	25 (32)	6 (11)	17.2***
	1.6–2	19 (25)	5 (10)	
	> 2	6 (8)	3 (6)	
Land access means	Own	67 (87)	38 (73.1)	
	Rent	4 (5.2)	6 (11.5)	9.01^{Ns}
	Share	6 (7.8)	8 (15.4)	
Cropland slope class	Moderate	25 (32)	10 (19)	15.1**
	Steep	38 (49)	23 (44)	
	Gentle	14 (19)	19 (37)	
Contact with DAs	Twice per month	19 (24.7)	7 (13.5)	
	Once per month	39 (50.6)	14 (27)	18.7***
	Rare per month	18 (23.4)	25 (48)	
Access to train	No contact	1 (1.3)	6 (11.5)	
	DAs	63 (81.8)	29 (55.8)	
	NRM expert	8 (10.4)	7 (13.5)	
	NGO	1 (1.3)	5 (9.6)	16.14**
	Media	2 (2.6)	5 (9.6)	
	Neighbours	3 (3.9)	6 (11.5)	

ns non-significant at P- value > .05

** Significant at P- value < 0.05

*** Significant at P- value < 0.001

structures malfunction, and sometimes aggravate erosion problems through facilitating conditions further erosion. Soil clay content, bulk density, moisture content, reaction, electrical conductivity, organic carbon, total nitrogen, and cation exchange capacity are changed with slope gradient; these soil properties become better at gentle slope than the steep. However, the contribution of graded soil bund for soil property improvement is relatively uniform among slope classes (steep, moderate and gentle). The observed difference in soil properties between slope classes is due to the effects of topography and past erosion events.

In the study area, most of the household heads participanted in soil conservation activities. Farmers land holding size, cropland slope, access to soil and water conservation trainings, and contact with extension workers are positively influence their participation in conservation activities. General, through providing quality extension services and training on soil and water conservation practices it is possible to enhance farmers participation and correct the technical limitations in bund spacing and vertical interval in the study area.

Final, future research on joint effects of topography (slope classes), conservation practices (soil bund), and space between consecutive bund on soil loss should be done.

Abbreviations

ANOVA: Analysis of Variance; CI: Confidence Interval; CSA: Central Statistical Agency of Ethiopia; FGD: Focused Group Discussion; GDP: Growth Domestic

Product; GLM: General Linear Model; Ha: Hectare; KI: Key Informant; LWARDO: Lemo Wordeda Agricultural and Rural Development Office; MoARD: Ministry of Agriculture and Rural Development of Ethiopia; SNNPRS: Southern Nation Nationalities and People's Regional State; SSA: Sub-Sahara Africa.

Authors' contributions

AB, EK made substantial contributions to conception and design, or acquisition of data, analysis and interpretation of data; AB, AA involved in drafting the manuscript or revising it critically for important intellectual content; AB, AA given final approval of the version to be published. Each author should have participated sufficiently in the work to take public responsibility for appropriate portions of the content; and AB, AA agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. AB produced map of the study area. All authors read and approved the final manuscript.

Author details

[1] Bureau of Agriculture and Natural Resource Management, Lemo District, Hosanna, Ethiopia. [2] Department of Natural Resource Management, College of Agriculture and Veterinary Medicine, Jimma University, Jimma, Ethiopia.

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Competing interests

The authors would like to declare that there is competing interests.

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All of the data and material are with authors, they available upon specific request.

Consent for publication

Not applicable.

Ethics approval and consent to participate

Not applicable because this research did not involved human subjects, material, or data.

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References

Abebe ZD, Sewnet MA (2014) Adoption of soil and water conservation practices in North Achefer District, Northwest Ethiopia. Chin J Popul Resour Environ 12(3):261–268

Ademe Y, Kebede T, Mullatu A, Shafi T (2017) Evaluation of the effectiveness of soil and water conservation practices on improving selected soil properties in Wonago district, Southern Ethiopia. J Soil Sci Environ Manag 8(3):70–79

Adimassu Z, Gorfu B, Nigussie D, Mowo J, Hilemichael K (2013) Farmers' preference for soil and water conservation practices in Central Highlands of Ethiopia. Afr Crop Sci J 21:781–790

Alemu B, Kidane D (2014) The implication of integrated watershed management for rehabilitation of degraded lands: case study of Ethiopian Highlands. J Agric Biodivers Res 3(6):78–90

Atnafe AD, Ahmed HM, Adane DM (2015) Determinants of adopting techniques of soil and water conservation in Goromti Watershed, Western Ethiopia. J Soil Sci Environ Manag 6(6):168–177

Ayalew A (2011) Construction of soil and water conservation structures for improvement of crops and soil productivity in the Southern Ethiopia. J Environ Earth Sci 1:21–29

Aytenew M (2015) Effect of slope gradient on selected soil physicochemical properties of Dawja watershed in Enebse Sar Midir District, Amhara National Regional State. Am J Scientific Ind Res 6(4):74–81

Bekele M, Lemenih M, Regassa A (2016) The effects of integrated soil and water conservation practices on soil physicochemical properties: the case of Menesibu District, West Ethiopia. J Nat Sci Res 6(23):35–45

Bezabih B, Aticho A, Mossisa T, Dume B (2016) The effect of land management practices on soil physical and chemical properties in Gojeb Sub-river Basin of Dedo District, Southwest Ethiopia. J Soil Sci Environ Manag 7(10):154–165

Birhanu A, Meseret D (2013) Structural soil and water conservation practices in Farta District, North Western Ethiopia: an investigation on factors influencing continued Use. Sci Technol Arts Res J 2(4):114–121

Bremmer J (1996) Total nitrogen In: Spark DL (eds) Methods of soils analysis and chemical method, 2nd ed. American Society of Agronomy, Soil Science Society of America, Madison, Wisconsin USA, pp. 1085–1121

Challa A, Abdelkadir A, Mengistu T (2016) Effects of graded stone bunds on selected soil properties in the Central Highlands of Ethiopia. Int J Nat Resour Ecol Manag 1(2):42–50

Cochran WG (1977) Sampling techniques, 3rd edn. Wiley, New York

CSA (2007) National population and housing census of Ethiopia. Addis Ababa, Ethiopia: the Federal Democratic Republic of Ethiopia, Central Statistical Agency (CSA)

Demelash M, Stahr K (2010) Assessment of integrated soil and water conservation measures on key soil properties in South Gonder, North-Western Highlands of Ethiopia. J Soil Sci Environ Manag 1(7):164–176

FAO (2006) Guideline for soil description, 4th edn. Stylus Publishing, LLC, Rome. ISBN 9789251055212

FAO (2007) Methods of analysis for soils of arid and semi-Arid Regions. Food and Agriculture Organization of the United Nations Rome, Italy, Rome

FEPA (2004) Guidelines on Soil and water conservation on Cultivated Land. Addis Ababa, Ethiopia

Gashaw T, Bantider A, Silassie HG (2014) Land degradation in Ethiopia: causes, impacts and rehabilitation techniques. Environ Earth Sci 4(9):98–104

Gebre T, Weldemariam D (2013) Farmers perceptions and participation on mechanical soil and water conservation techniques in Kembata Tembaro Zone: the case of Kachabirra Woreda, Ethiopia. Int J Adv Struct Geotech Eng 2(4):118–131

Gebre T, Mohammed Z, Taddesse M, Narayana SCh (2013) Adoption of structural soil and water conservation technologies by small holder farmers in Adama Wereda, East Shewa, Ethiopia. Int J Adv Struct Geotech Eng 2(2):58–68

Getachew Z (2014) The effectiveness and challenges of soil and water conservation practices in Raya Azebo Woreda of Tigray, Ethiopia. Doctoral dissertation, Addis Ababa University, Ethiopia

Ghasemi A, Zahedias S (2012) Normality tests for statistical analysis: a guide for non-statisticians. Int J Endocrinol Metab Spring 10(2):486–489

Hailu W, Moges A, Yimer F (2012) The effects of 'fanya juu'soil and water conservation structure on selected soil physical and chemical properties: the case of Goromti watershed, western Ethiopia. Resour Environ 2(4):132–140

Hurni H, Abate S, Bantider A, Debele B, Ludi E, Portner B, Yitaferu B, Zeleke G (2010) Land degradation and sustainable land management in the highlands of Ethiopia. In: Hurni H, Wiesmann U (eds) with an international group of co-editors. Global change and sustainable development: a synthesis of Regional experiences from research partnerships. Perspectives of the Swiss national centre of competence in research (NCCR) North-South, University of Bern, Vol. 5. Geographica Bernensia. Bern, Switzerland

IBM Corp (2011) IBM SPSS statistics for windows, version 20.0. IBM Corp, Armonk

LWARDO (2009) Land use type profiles and annual reports. Lemo Woreda Agricultural and Rural Development Office (LWARDO) (Unpublished)

Masresha B (2014) Evaluation of soil and water conservation measures in Dejiel Watersheds, Choke Mountains, East Gojjam Zone of Amhara Region, Ethiopia. Doctoral dissertation, Addis Ababa University, Ethiopia
Mekonen K, Tesfahunegn GB (2011) Impact assessment of soil and water conservation measures at Medego watershed in Tigray, northern Ethiopia. Maejo Int J Sci Technol 5(3):312–330
Meshesha YB, Birhanu BS (2015) Assessment of the effectiveness of watershed management intervention in Chena Woreda, Kaffa Zone, Southwestern Ethiopia. J Water Resour Protect 7(15):1257–1269
MOARD (2005) Managing land. A practical guidebook for development agents in Ethiopia. Ministry of Agriculture and Rural Development (MoARD), Ethiopia, Addis Ababa
Molla T, Sisheber B (2017) Estimating soil erosion risk and evaluating erosion control measures for soil and water conservation planning at Koga watershed in the highlands of Ethiopia. Solid Earth 8:13–25
Pimentel D (2006) Soil erosion: a food and environmental threat. Environ Dev Sustain 8(1):119–137
SAONREPA (2004) Farmers practical training manual on watershed development. South Ethiopia 39:28–29
Selassie YG, Anemut F, Addisu S (2015) The effects of land use types, management practices and slope classes on selected soil physicochemical properties in Zikre watershed, North-Western Ethiopia. Environ Syst Res 4(1):3
Sinore T, Kissi E, Aticho A (2018) The effects of biological soil conservation practices and community perception toward these practices in the Lemo District of Southern Ethiopia. Int Soil Water Conserv Res 6(2):123–130
Tesfaye G, Kasahun KH (2015) Assessment on farmers' practices on soil erosion control and soil fertility improvement in Rift Valley Areas of East Shoa and West Arsi Zones of Oromia, Ethiopia. Agric Res Article. 10:391–400
Van Reeuwijk LP (1992) Procedures for soil analysis, 3rd edn. International Soil Reference Center (ISRIC), Wageningen, the Netherlands
Vlek P, Bao Le Q, Tamene L (2008) Land decline in land-rich Africa: a creeping disaster in the making, pp 12–54
Waling I, VanVark W, Houba VJG, Vanderlee JJ (1989) Soil and Plant Analysis, A series of syllabi. Part 7. Plant Analysis Procedures. Wageningen Agriculture University, Netherland, pp. 712–717
Walkley A, Black IA (1934) An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil Sci 37(1):29–38
Wolancho KW (2015) Evaluating watershed management activities of campaign work in Southern nations, nationalities and peoples' regional state of Ethiopia. Environ Syst Res 4(1):6
Wolka K, Negash M (2014) Farmers' adoption of soil and water conservation technology: a case study of the Bokole and Toni Sub-Watersheds, Southern Ethiopia. J Sci Dev 2(1):35–48
Wolka K, Moges A, Yimer F (2011) Effects of level soil bunds and stone bunds on soil properties and its implications for crop production: the case of Bokole watershed, Dawuro zone, Southern Ethiopia. Agric Sci 2(3):357–363
Yeshaneh GT (2015) Effect of slope position on soil physico-chemical properties with different management practices in small holder cultivated farms of Abuhoy Gara Catchment, Gidan District, North Wollo. Am J Environ Protect 3(5):174–179
Yimer F, Ledin S, Abdelkadir A (2006) Soil property variations in relation to topographic aspect and vegetation community in the south-eastern highlands of Ethiopia. For Ecol Manage 232(1):90–99