Journal of Science and Sustainable Development (JSSD), 2026, 14(2), 1-13

ISSN: 2304-2702 (print); 2414-4479 (online)
DOI: 10.20372/au.jssd.14.2.2026.0749

RESEARCH PAPER

Assessing Community-Based Watershed Management: Technical Quality of Soil Conservation Structures and Their Impacts on Soil Properties in Belo-Chikle Micro-Watershed, Elfeta District, Oromia, Ethiopia

Birhanu Kebede Kuris* and Melkamu Alemu

College of Natural and Computational Sciences; Department of Biology, Ambo University, Ambo, Ethiopia

***Corresponding Author:** Email: taddeebirruu@gmail.com*

Abstract

Soil erosion is one of the major causes of food insecurity and environmental degradation in Ethiopia. In recent years, a community-based watershed management program has been introduced in Ethiopia. In Elfeta District, there is a lack of tangible scientific information on the performance of soil conservation practices implemented through this program. The aim of this study was to assess the technical fitness of physical soil conservation structures implemented via a community-based watershed management program, its effect on soil physicochemical properties, and the extent of farmers' participation in the program. Field observation and physical structure component measurements 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. A structured questionnaire was used to assess farmers' participation in soil conservation. As compared to the nationally established specification of graded soil bund for areas similar to Elfeta District, technical errors were found in bund spacing and vertical interval. The soil moisture content, bulk density, clay content, pH, electrical conductivity, organic matter, total nitrogen, and cation exchange capacity were significantly ($p < 0.05$) affected by slope gradient. These properties become better as the slope gradient decreases. To ensure the sustainability of watershed management practices and minimize observed technical faults on conservation structures, continued technical support, trainings, and follow-ups are required from the districts' experts and extension services in the study area.

Keywords: Watershed management, physical structure, soil erosion, soil and water conservation

Introduction

Land degradation remains one of the biggest environmental problems worldwide, threatening both developed and developing countries, and it has been a major global agenda because of its adverse impact on the environment, food security, and quality of life (Slegers, 2008). Land degradation includes all processes that diminish the capacity of land resources to perform essential functions and services in ecosystems (Hurni *et al.*, 2010). Principal processes of land degradation include erosion by water and wind, chemical degradation (comprising acidification, salinization, fertility depletion, and decrease in cation retention capacity), physical degradation (comprising crusting, compaction, hard-setting, etc.), and biological degradation (reduction in total and biomass carbon and decline in land biodiversity) (UNCCD, 2024; Reddy *et al.*, 2018). Erosion affects soil physical conditions (e.g., reduction of soil thickness and capacity to hold water) and chemical properties (e.g., loss of nutrients), impacting agricultural production (Hurni *et al*., 2010). Therefore, soil erosion has a negative impact on the environment, agricultural productivity, food safety, and overall quality of life (Atnafe *et al*., 2015). Nearly all Sub-Saharan Africa (SSA) lands are vulnerable to soil depletion, and Ethiopia is one of the countries most affected by land degradation problems (Bekele and Drake, 2003).

According to Pimentel (2006) and Mekonen and Tesfahunegn (2011), approximately 10 million hectares of cropland are abandoned worldwide each year and 6.5 million hectares in Africa. Mulugeta and Stahr (2010) also indicate that every year, around 12 tons/(ha/year) of soil is lost in Ethiopia due to erosion, and the economic impact of this loss is estimated at around $139 million, which significantly affects the country's domestic agricultural product (GDP) growth.

The major reasons why land degradation remains a problem all over the world are lack of appropriate identification and evaluation of the degradation processes and of the cause-and-effect relations of soil degradation for each specific situation and the generalized use of empirical approaches to select and apply soil and water conservation (SWC) practices. Sometimes, wrong selection and implementation of soil and water conservation practices and structures may increase land degradation processes and derived environmental impacts (Pla Sentís, 2002). Gizaw *et al*. (2019) also stated that the problems of land degradation are increasing throughout the world due to the generalized use of empirical approaches to select and apply soil and water conservation (SWC) practices. Yericho and Belay (2015) also pointed out that poor community participation, lack of structural alignment with standards, inappropriate time of implementation, lack of diversified SWC measurements, and absence of regular maintenance and management of the structures were some of the major limitations of the intervention. Therefore, the design of SWC structures considers the extent of erosion, cause of erosion, and suitability of land (Gizaw *et al*., 2019). The same finding discovered that lack of training, extension service, lack of farm tools, and skilled manpower are the major problems during SWC structure implementation.

The soil and water conservation system in Ethiopia was launched in the 1970s with the aid of international organizations. The focus of the launched conservation system was to reduce soil degradation, improve agricultural production, enhance food security, and reduce poverty. Twenty years ago, national soil and water conservation initiatives (community-based programs) were promoted to ensure sustainable development of the environment, food security, and socio-economic development (Yericho and Belay, 2015). Some conservation practices implemented through this project can minimize soil erosion in Ethiopia's highlands, improve basic soil conditions such as pH, cation exchange capacity (CEC), electrical conductivity (EC), organic content (OC), etc., and increase crop yields (Adimassu *et al*., 2013; Bekele and Drake, 2003).

Soil and water conservation technology in many parts of Ethiopia has not been equally successful or effective, and farmers' participation remains below expectations. Constraints such as technical skill gaps, inadequate field guidance, weak extension support, and insufficient post-implementation follow-up have been identified as significant barriers to sustained participation and maintenance (Hassen *et al*., 2021; Kedir *et al*., 2025; Kebede and Mesele, 2014; Lemike *et al*., 2026). Even though successful stories from northern Ethiopia are reported, there is limited scientific evidence that justifies the success of soil conservation technology in central Ethiopia, including Elfeta District.

In recent years, national soil and water conservation campaigns (mass community programs) have been introduced in Ethiopia to guarantee sustainable development of the watershed, food safety, and socio-economic growth (Yericho and Belay, 2015). However, successful stories from northern Ethiopia are reported; mass mobilization approaches lead to the implementation of soil and water conservation structures with inappropriate design, and consequently, soil conservation activities have had a lesser impact than expected and resulted in gully formation in many parts of the country. Such a problem may be due to a technical gap and lack of trained manpower (Gizaw *et al*., 2019). The technical gap causes failure of implemented SWC technologies, which in turn causes serious land degradation. The failure of implemented structures was observed and reported repeatedly in most parts of the country due to wrong SWC structure design specification (Gizaw *et al*., 2019; Yericho and Belay, 2019). Now a days millions of hectares of land are covered with procedures for soil and water conservation nationally, including the study area. Similarly, Tamiru and Gemechu (2016) indicated that that soil and water conservation structures implemented via mass-community mobilization programs and individual farmer initiatives are becoming popular solutions to minimize the impacts of land degradation in the study area.

In spite of having the aforementioned efforts on watershed management development, the effectiveness of the intervention was not often evaluated in many parts of the country. The experience in Ethiopia showed that the practice of evaluation of the effectiveness of the project is overlooked for three main reasons, such as lack of political administrative commitment, insufficiency of budget allocated for monitoring and evaluation, and inadequacy of the institutional arrangements that underlie monitoring and evaluation (Wassie, 2000). Therefore, the objective was to assess the community-based watershed management practices: focus on the technical fitness of the physical structure and its effect on selected soil physicochemical properties in the Belo-Chikle micro-watershed, as the watershed is very important for natural resource conservation and agricultural production.

Materials and methods

Description of Study Areas

The study area-Elfeta District is located in West Shoa Zone, Oromia National Regional State, Ethiopia with a central geographical position of 9°7′0″N37°58′0″E. The district is located 126 km South-West of Addis Ababa the capital of Ethiopia and as wall as the capital of the National Regional State Oromia and at 68 km North of Ambo town the administrative center of West Shoa zone (Fig. 1). The district is delineated by Chobi and Jeldu to North, Dandi to East and Ambo District in South and West Direction. Elfeta District has total land area of 39,342 hectares out of which 66% of the area is used for farming, 19.57% of the area is used for grazing, 9.3 % of the area is covered by forest, 2.5% of the area is covered by river and water bodies and 2.78% hectares are unusable land (EDADO, 2018).

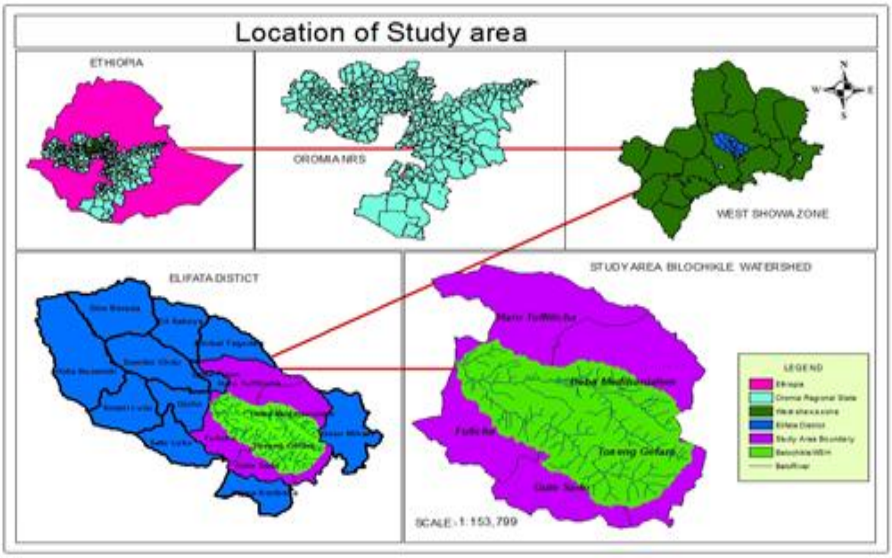

Figure 1. Map of the study area

The Belo-Chikle micro watershed is found in the highland of the district, covers total land area of 540 ha and encompass Toseng-gefere Kebele entirely and partial part of other four kebeles (Deba-medhanelem, Haro-Tufticha, Fallicha and Gute-sado). It is the largest watershed of the district and it was the area where the community-based watershed management practice adopted (EDADO, 2018). The total households of the watershed were 1719m^2. Amanuel (2018) and Yericho (2019) the study area has been categorized in to 1–7% gentle slope, 7–15% moderate slope, and 15–30% steep slope. The mean annual rainfall ranges from 900 - 1400 mm whereas the minimum and maximum temperatures are 13 and 23°C, respectively and average mean 16℃ (EDADO, 2018).

The geology of central high land of the country is characterized by late tertiary that covers the Pre-Cambrian rocks that underlie all other rocks in Ethiopia (Mohr, 1971). Throughout the Blue Nile basin in Ethiopia the soils are generally Vertisols or Laptosols. The Upper basin is mainly formed from clay and clay-loam soil type, but the riverbed has a loam and sandy loam type of soil. The dominate soil types of the area (Belo-Chikle micro-watershed) is Nitisols (EDADO, 2018) which are among the most extensive agricultural soil in the Ethiopian highlands but soil degradation threatens their productive capacity.

Tamiru (2016) indicated that, contour plowing, traditional ditches, cut off drain and Water ways, soil bund and stone bund are the most common conservation methods practiced in the district including the study micro watershed to reduce soil erosion. Fallowing was rarely implemented due to lack of inadequate land.

Methods of Data Collection

Direct field observations and measurements of physical soil and water conservation structures (graded soil bonds) implemented through mass-community mobilization campaigns were used to evaluate the technical fitness of the study area conservation practices. The observations and measurements were carried out on six separate fields located on gentle, moderate, and steep slope classes. Using a tape meter, water level, string (rope), and graduated poles, field measurements of soil bunds, embankment height, embankment top width, embankment bottom width, ditch depth, ditch size, berm length, vertical interval, and space between bunds were performed.

The composite soil samples were collected from croplands situated at moderate, steep, and gentle slopes treated with soil bund through a mass-community mobilization program in the delineated micro watershed. The soil samples were collected from 1, 2, and 4 m away from soil bunds using an auger at 0–15 cm sampling depth. A total of 27 composite samples were collected for laboratory analysis. In addition, undisturbed core samples were taken to determine soil bulk density and moisture content.

The sample size of HHs for the study is 117 HHs, which was determined by using the formula developed by Kothari (2004) at a confidence level of 95% and an expected error of 0.05. A proportional sampling technique was employed to decide the numbers of respondent households from each slope class. Accordingly, 48, 40, and 29 HHs were sampled from gentle, moderate, and steep slope classes, respectively, based on their total population (i.e., 699, 427, and 593). Lists of household heads recorded at the village (locally called "kebele") administrative office were used as a sample frame for random selection of the households for the questionnaire and face-to-face interview. Besides, focused group discussions (FGD) and key informant (KI) interviews were used to triangulate and supplement the information acquired from the household survey.

Soil Laboratory Analysis

Selected soil physicochemical parameters were analyzed at the Soil Laboratory of Ambo University. The samples were air-dried, ground, and passed through 2 mm soil sieve mesh for soil texture, pH, electrical conductivity, organic carbon, total nitrogen, available phosphorous, and cation exchange capacity of the soil. Soil particle size distribution was determined by using the 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 agents. Bulk density was determined by the core method, the ratio of solid mass to total volume of the core sample after the soil was dried in an oven at 105°C for 24 hrs.

The soil reaction (pH-H_2O) was measured using the 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 solutions 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 an EC meter. Total nitrogen was determined using Kjeldahl digestion, distillation, and titration procedures (Bremmer, 1996). Soil organic carbon was determined following the wet digestion and titration method of Walkley and Black (1934), whereas soil organic matter content was computed from OC. The available soil phosphorous was extracted using the Bray-II method (Van Reeuwijk, 1992), and P in the extract was measured via spectrophotometer at a wavelength of 882 nm. Soil cation exchange capacity (CEC) was determined after leaching the soil sample with the 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 properties. The ANOVA was performed following the General Linear Model (GLM) procedure at a probability (P) of .05 and a confidence interval (CI) of 95%. After checking the assumptions of ANOVA, the main and interaction effects of the independent variables (soil parameters) were analyzed using SPSS version 20 software. Normal distribution and confidence interval of the soil dataset were tested using the Shapiro–Wilk test. The chi-square test was used to assess the effect of socio-economic and demographic factors on farmers' participation in soil conservation practices. In addition, the binary logistic regression model was used to analyze the relationship between the dichotomous dependent variable and the independent variables (Park, 2013). It enables determining the impact of multiple independent variables on the dependent variable.

Table 1. Nationally recommended specifications of graded soil bunds for areas similar to the study area

Bund components	Embankment height	Embankment top width	Embankment bottom width	Berm length	Ditch Depth)	Ditch width	Length
Average Recommended/Specification standards (m)	0.50	0.45	1.30	0.25	0.50	0.40	70

Source: FEPA (2004) and Gizaw *et al*. (2019)

Results and Discussion

Technical Fitness of Physical Soil and Water Conservation Structures

Graded soil bund was the common soil and water conservation structure built at croplands situated in different slope classes (steep, moderate, and gentle). As proposed, six separate crop fields were identified, and important soil bund dimensions, including embankment and spacing, as well as soil bund channel dimensions, were measured and computed with national standard values.

The observed and measured field results indicated the structure components (embankment top width, embankment bottom width, berm length, ditch width, and ditch depth) of bunds constructed at the study area were compatible with the national specifications (Table 1). Similarly, the constructed soil bund channel dimensions at the study area were matched with standard and calculated specifications. But the space between successive bunds deviated with -1m, vertical interval deviated with -0.8 m bottom width deviated with -0.05m and bund length deviated with -10m (at field number 5), vertical intervals deviated with -0.8m, spacing deviated with -1m, embankment height deviated with +0.05 m, embankment top width deviated with +0.01 m, bottom width deviated with -0.05 m bund length deviated with -10 m(at field number 6), embankment bottom width deviated -0.05 m (at field number 1), embankment height deviated with -0.05 m and bottom width deviated with -0.05 m (at field number 2), and the ditch width (at field number 5) deviated with -0.05 m of the components built through mass-community mobilization program on croplands of the study area were incompatible with the national specifications.

Table 2. Comparison of implemented and standard soil bund embankment and spacing

Field No.	Slope (%)	Dimension	Soil Bund Embankment and Spacing		Deviation
			Implemented (m)	Standard (m)	
1	6	Spacing	20.00	20.00	0.00
		Vertical Interval	1.20	1.20	0.00
		Height	0.50	0.50	0.00
		Top width	0.45	0.45	0.00
		Bottom Width	1.25	1.30	-0.05
		Length	70.00	70.00	0.00
		Berm Length	0.25	0.25	0.00
2	6	Spacing	20.00	20.00	0.00
		Vertical Interval	1.20	1.20	0.00
		Height	0.45	0.50	-0.05
		Top width	0.45	0.45	0.00
		Bottom Width	1.25	1.30	-0.05
		Length	70.00	70.00	0.00
		Berm Length	0.25	0.25	0.00
3	12	Spacing	15.00	15.00	0.00
		Vertical Interval	1.80	1.80	0.00
		Height	0.50	0.50	0.00
		Top width	0.45	0.45	0.00
		Bottom Width	1.30	1.30	0.00
		Length	70.00	70.00	0.00
		Berm Length	0.25	0.25	0.00

		Spacing	14.00	140	0.00
		Vertical Interval	2.10	2.10	0.00
		Height	0.50	0.50	0.00
4	15	Top width	0.45	0.45	0.00
		Bottom Width	1.30	1.30	0.00
		Length	70.00	70.00	0.00
		Berm Length	0.25	0.25	0.00
		Spacing	14.00	13.00	-1.00
		Vertical Interval	2.60	1.80	-0.80
		Height	0.55	0.55	0.00
5	20	Top width	0.51	0.51	0.00
		Bottom Width	1.45	1.40	-0.05
		Length	70.00	60.00	-10.00
		Berm Length	0.25	0.25	0.00
		Spacing	14.00	13.00	-1.00
		Vertical Interval	2.60	1.80	-0.80
		Height	0.50	0.55	0.05
6	20	Top width	0.50	0.51	0.01
		Bottom Width	1.45	1.40	-0.05
		Length	70.00	60.00	-10.00
		Berm Length	0.25	0.25	0.00

The space between successive bunds of the components built on croplands at the steep slope class through the mass-community mobilization program was meaningfully wider than the recommended standards or calculated specification (Table 2). The results of key informant and focused group discussions revealed that the area where the community was continually assisted by extension services and situated on the gentle and moderate slope better performed the entire bund structure dimension computed to the given standards. The farmers situated in the steep slope area feel more about the size of the farmland occupied by the conservation structure than the quality of the work. The farmers focused on the quantity (area coverage with bund) rather than the quality of the activities.

The key informant and focused group discussion revealed that the reason why the problems observed related to the physical fitness of the conservation structure were due to lack of sufficient training and technical support during the construction and misunderstanding of the farmers on the importance of space between bunds and the vertical interval. The wider spaces between bunds were preferred by farmers to minimize possession of cultivable areas with physical structures. Unlikely, wider space between bunds may cause the formation of erosion in cropland and needs more labor for maintenance of bunds.

The work of Yericho (2015) revealed the imperfect physical structure is ineffective in controlling erosion and requires immediate repairs. Inadequate technical support for farmers is reported as a cause for ineffective soil and water conservation practices (Kebede, 2015). When the space between soil and water conservation structures is wider than the required space, the risk of soil erosion on cropland could increase (Amanuel *et al*., 2018; Tegenge and Biniam, 2017; Yericho, 2019).

Table 3. Comparison of implemented and standard soil bund channel dimensions

Field No.	**Slope (%)**	**Dimension**	**Soil Bund Channel Dimension**		
			Implemented (m)	**Standard (m)**	**Deviation**
1	6	Depth	0.48	0.50	-0.02
		Width	0.30	0.30	0.00

2	6	Depth	0.48	0.50	-0.02
		Width	0.30	0.30	0.00
3	12	Depth	0.50	0.50	0.00
		Width	0.40	0.40	0.00
4	15	Depth	0.50	0.50	0.00
		Width	0.40	0.40	0.00
5	20	Depth	0.50	0.50	0.00
		Width	0.35	0.40	-0.05
6	20	Depth	0.50	0.50	0.00
		Width	0.40	0.40	0.00

On top of this, the vertical interval of bunds constructed at the steep slope of the study area was lower than the national standard; this could facilitate surface runoff and destruction of bunds as well as croplands via allowing accumulation of water in the bunds. As rainwater accumulated inside the structures, soil erosion and runoff damaged the constructed structures (Table 3). This agrees with Tegenge and Biniam (2017), who reported that when the vertical interval of a graded soil bund is lower than the required standard, a huge amount of runoff can be generated and cause damage to the bund embankment and croplands.

Effects of Soil Bund on Soil Properties

The slope position was significantly ($p < 0.05$) affected soil clay content in the study area but soil-sampling distance from bunds was non-significantly ($p > 0.05$) affected the studied soil properties. A high clay proportion was observed at gentle slope and low at steep slope, as the slope gradient increases clay content declined. The distribution of clay content of the soil sample was different among slope classes. Thus, the clay contents of the soil increase as the slope gradient (degree of elevation) decrease. A high clay proportion was observed at gentle slope (23.72%) and low at steep slope (12.58), this indicated as the slope gradient of the sample increases the clay content (%) declined). Supporting this, the estimated marginal means of clay (%) contents of the soil sample revealed the clay (%) contents of the soil sample increases as the slope of the sample gradient decreases. 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. Study by Muche and Molla (2024), reported that a slope position has meaningful effect on soil texture through its influence on soil formation and erosion processes. Soil and water conservation structures influence the processes of soil erosion and deposition at different slope position (Adimassu *et al*., 2013).

Similar to clay contents, the moisture contents of the soil vary among slope classes, and high moisture content was observed at gentle slopes (7.11%) and low at steep slopes (4.4%), indicating that as the slope gradient of the sample decreases, the moisture content of the soil increases (Table). The estimated marginal means of moisture (% content in the soil sample increase as the slope of the sample gradient decreases. Amanuel *et al*. (2018) also found that the soil moisture increases along the slope gradient; this is due to the nature of water movement, low bulk density, clay content, and soil organic matter content. Similarly, Abay *et al*. (2016) reported that the soil moisture increased at low bulk density and high soil organic matter content.

The soil bulk density was different along slope classes, and the bulk density (g/cm³) of the soil increases as the slope elevation goes up (Table 3). The lowest bulk density was recorded at a gentle slope (0.60 g/cm³) and the highest at a steep slope (1.07 g/cm³). The estimated marginal means of bulk density (g/cm³) of the soil sample increases as the slope of the sample gradient decreases. Similarly, Amanuel *et al*. (2018) found that the change in soil bulk density along slope position was attributed to soil organic carbon and clay fraction. Hailu *et al*. (2012) also reported that the bulk density rises with organic carbon and accumulation of crop residues. Moreover, soil bulk density is directly related to slope position, and as the slope gradient increases, bulk density also increases and vice versa (Bezabih *et al*., 2016).

The pH value of the soil varies between different slope classes, and the value was decreasing as the slope elevation degree increases (Table). Accordingly, a high pH value (5.82) was observed at the gentle slope and the lowest (3.98) at the steep slope. The estimated marginal means of the pH (H_2O) value of the soil sample increases as the slope of the sample gradient decreases. The presence of the highest soil pH at a gentle slope was associated with high soil OC, CEC, and clay fraction moved with runoff and erosion from steep slope positions (Amanuel *et al*., 2018). Fantaw *et al*. (2006) also stated that the surface runoff in steep slopes decreases soluble basic cations, increases H+ activity, and reduces soil pH value.

The electrical conductivity of the soil was affected by slope position (Table). The electrical conductivity of the soil has an inverse relation with the slope gradient. Thus, a relatively higher EC (0.80 dS/m) was recorded at a gentle slope and a lower one (0.045 dS/m) at a steep slope. The estimated marginal means of the electrical conductivity (dS/m) of the soil sample increases as the slope of the sample gradient decreases. Similarly, Amanuel *et al*. (2018) stated Electrical conductivity inversely related with slope gradient 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. Also, Bezabih *et al*. (2016) found that EC differs along slope position due to runoff and soil erosion processes that affect soil basic cations.

The soil organic matter was differing in terms of slope classes. The result indicated that as one goes through slope classes from steep slope to gentle, the content of organic matter increases, and the highest amount (14.02%) was recorded at gentle slope and the lowest (11.04%) at steep slope. The estimated marginal means of organic matter of the soil sample increase as the slope of the sample gradient decreases. Likewise, Amanuel *et al*. (2018) explained that in the rain area, a high amount of organic carbon exists at the lower watershed area (gentle slope). This could be due to the removal of organic matter through erosion and surface runoff from steep slopes and deposition in gentle slopes, and the presence of better soil moisture at gentle slopes. Higher clay fractions are typically found at lower slope positions due to deposition from upper slopes (Hailu *et al*., 2012).

The distribution of total nitrogen was affected by slope position; thus, the highest amount of total nitrogen content was recorded at a gentle slope (1.93%) and the lowest at a steep slope (0.86%). The estimated marginal means of total nitrogen of the soil sample increase as the slope of the sample gradient decreases. This could be due to the removal of nitrogen with organic matter through erosion and surface runoff from steep slopes and deposition in gentle slopes, and the presence of better soil moisture at gentle slopes. But in the case of the sample distance of the bund, there were no meaningful differences among the contents of nitrogen. The soil nitrogen content decreases with increasing slope; the content was low at steep slopes and high at gentle slope positions (Mulugeta, 2015). The removal of nitrogen with organic matter through erosion and surface runoff from steep slopes and deposition in gentle slopes, and the presence of better soil moisture at gentle slopes (Amanuel *et al*., 2018).

The distribution of cation exchange capacity of the soil was varied along slope gradients; thus, the soil cation exchange capacity has an inverse relation with degree of elevation. The highest amount was recorded at a gentle slope (43.09 meq/100 g) and the lowest at a steep slope (27 meq/100 g) (Table). The estimated marginal means of cation exchange capacity of the soil sample increases as the slope of the sample gradient decreases.

Factors Affect Farmers Participation in Soil and Water Conservation Practices

The binary logit model was used to identify determinant factors that influence the level of farmers' participation in SWC practices (materials and methods). The result revealed that HH's gender (GEND), extension contact (EDAC), slope of plot (LSLOP), number of livestock of the household (LIVSTK), land holding or farm size (FRMSIZE), land use type (LANDUS), perceived profitability of the structure (PPRF), perception of SWC structure (PRCST), and average distance of HHs from farm plot (AVD) variables were found to significantly affect the level of farmers' participation in SWC practices (Table 4). Other variables like farmer age (FARMAGE), HHs educational level (EDULEVEL), HH family size (FS), availability of training (TRAN), land security (LANDSECU), labor availability (LABOAVA), and soil fertility status of the plot (SOFR) had no significant relation to the level of farmers' participation in SWC practices (Table 4).

Table 4. Binary Logit Model Output of Determinant Factor

Variables	***B***	***S.E.***	***Wald***	***Df***	***Sig.***	***Exp(B)***
HH AGE	-15.319	2413.814	1.806	1	0.179	0.000
HH EDU.	0.168	2039.577	0.246	1	0.620	1.183
HH FS	-16.140	1516.137	0.230	1	0.632	0.000
GEND	18.931	17992.637	4.770	1	0.029	6.011
LANDSECU	31.293	3040.084	1.119	1	0.290	7.336
TRAN	-0.848	3795.866	0.413	1	0.520	0.428
EDAC	33.355	3887.637	6.042	1	0.014	8.500
FRMSIZE	-39.471	5832.303	69.625	1	0.000	0.000
LSLOP	17.431	5539.184	33.843	1	0.000	0.000
SOFR	11.051	3096.539	2.287	1	0.130	2.213
LABOAVA	2.420	7552.469	0.092	1	0.761	11.244
LIVSTK	-5.838	3873.455	35.228	1	0.000	0.003
PRCST	1.383	6104.891	6.964	1	0.008	3.988
PPRF	17.047	2602.091	42.274	1	0.000	7.450
AVD	-30.493	0.576	4.758	1	0.000	5.375
LANDUS	-0.29	0.823	47.703	1	0.029	1.749
Constant	-87.523	41381.622	1.806	1	0.000	0.000

Chi-square=139.202
-2log likelihood= 6.165a
Cox and Snell R Square =0.679
Nagelkerke R Square= 0.976
No. of observation:117
HH=Household, AGE=Age, EDU=Education, FS= family size, GEND=Gender, SCUL= Land security, TRAN= Available of training, EDAC=Extension contact, FRMSIZE=Farm size, SLP=Slope of plot, SOFR=Soil fertility status of the plot, LABA= Labour availability, PRCST=Perception on structure, PRRF=Perceived profitability of the structure, LANDUS=Land use type, AVD= average distance of a plot from homestead

Conclusion and Recommendations

Conclusion

Community-based watershed management practices are one of the most important approaches used to address soil erosion and land degradation problems. Most of the physical soil and water structures built through this program in the Belo-Chikile micro-watershed were technically fit with the national standard of similar to the study area. But at the steep slope area, the space between consecutive bunds was meaningfully wider than the national standard, and the vertical interval is below the calculated value. These limitations are potential causes for soil conservation structure malfunction and sometimes aggravate erosion problems through facilitating conditions for further erosion. Soil reaction (pH), clay content, bulk density, moisture content, electrical conductivity, organic carbon, total nitrogen, and cation exchange capacity are changed with slope gradient, and all the above soil properties become better at gentle slopes than steep ones. 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. Most participate in soil conservation activities. The extension contacts, slope of plot, perceived profitability of the structure, perception of SWC structure, and average distance of the farm plot have positive and significant influence on the decision to participate in the community-based watershed management practices of the household heads. The amount of livestock on the household, landholding or farm size, and land use type have a negative and significant influence on the adoption of soil and water conservation measures.

Recommendations

Most of the farmers actively participated in the program; by providing quality extension services and training on soil and water conservation practices, it is possible to enhance farmer participation and correct the technical limitations observed on bund spacing and vertical interval. This implies that the regional and local administrations should provide extension and training services on the introduced SWC practices for the farmers and agricultural extension service workers. The District Agricultural Offices should take into account these determining factors to supplement the farmers' participation in the program. These measures encourage farmers to take soil and water conservation practices on their farmlands and at the level of watershed.

Conflict of Interest

The authors declare no conflict of interest.

Funding

No financial support was provided to carry out this research. We did from our pocket.

Availability of Data and Material

The data will be made available upon request.

Authors contribution

Birhanu Kebede Kuris provided conceptualization, validation, supervision, writing – review & editing; Melkamu Alemu did conceptualization, investigation, formal analysis, validation and, writing – original draft

References

Abay, C., Abdelkadir, A. & Mengistu, T. (2016). Effects of graded stone bunds on selected soil properties in the Central Highlands of Ethiopia. *International Journal of Natural Resources Ecology and Management*, 1(2), 42–50.

Adimassu, Z., Gorfu, B., Nigussie, D., Mowo, J., & Hilemichael, K. (2013). Farmers' preference for soil and water conservation practices in central highlands of Ethiopia. African Crop Science Journal, 21(3), 781–790.

Amanuel, B., Abebayehu, A. & Endalkachew, K. (2018). 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. *Environmental Systems Research*, *7*, 20. Article 20

Atnafe D., Ahmed, M. & Adane, M. (2015). Determinants of adopting techniques of soil and water conservation in Goromti Watershed, Western Ethiopia. *Journal of Soil Science and Environmental Management*, 6(6), 168–177.

Bekele, W. & Drake, L. (2003). Soil and water conservation decision behavior of subsistence farmers in the Eastern Highlands of Ethiopia: A case study of the Hunde-Lafto area. *Ecological Economics*, 46(3), 437–451.

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. *Journal of Soil Science and Environmental Management*, 7(10), 154–165.

Bremmer, J. (1996). Total nitrogen. In D. L. Sparks (Ed.), *Methods of soil analysis:*

Part 3. Chemical methods (pp. 1085-1121). American Society of Agronomy; Soil Science Society of America.

Elfeta District Agriculture and Development Office (EDADO) (2018). *Annual report* (Unpublished report).

Federal Environmental Protection Authority (FEPA) (2004). *Guidelines on soil and water conservation on cultivated land*. Addis Ababa, Ethiopia.

Fantaw, Y., Ledin, S & Abdelkadir, A. (2006). Soil property variations in relation to topographic aspect and vegetation community in the south-eastern highlands of Ethiopia. *Forest Ecology and Management*, 232(1), 90–99.

Food and Agriculture Organization (FAO) and Intergovernmental Technical Panel on Soils (ITPS) (2015). *Status of the world's soil resources (SWSR): Main report*. FAO.

Gizaw, T., Kalkidan, F., Yalemtsehay, D. & Leta, H. (2019). Evaluating technical standards of implemented soil and water conservation technologies in Jimma Zone, Southwestern Ethiopia. *Agricultural Research and Technology: Open Access Journal*, 19(4). Article 556100

Hassen, G., Bantider, A., Legesse, A., Maimbo, M., & Yildiz, F. (2021). Assessment of design and constraints of physical soil and water conservation structures in respect to the standard in the case of Gidabo sub-basin, Ethiopia. Cogent Food & Agriculture, 7(1), 1855818.

Hailu, W., Moges, A., & Yimer, F. (2012). The effects of 'Fanya juu' soil conservation structure on selected soil physical & chemical properties: The case of Goromti Watershed, Western Ethiopia. Resources and Environment, 2(4), 132–140.

Hurni, H., Abate, S., Bantider, A., Debele, B., Ludi, E., Portner, B. & Birru, Y. (2010). Land degradation and sustainable land management in the highlands of Ethiopia. In: Hurni, H. & Wiesmann, U. (Eds.), *Global change and sustainable development: A synthesis of regional experiences from research partnerships*, (Vol. 5, pp. 187–207). Geographica Bernensia.

Kebede, W. & Mesele, N. (2014). Farmers' adoption of soil and water conservation technology: A case study of the Bokole and Toni sub-watersheds, southern Ethiopia. *Journal of Science & Development*, 2(1), 35–48.

Kedir, J. B., Tadesse, T. B., Umer, S., Kufa, A. & Erango, S. T. (2025). Beyond implementation: Assessing farmers' perception of the sustainability of soil and water conservation measures in central Ethiopia. *Discover Sustainability*, 6, Article 02464.

Kothari, C. R. (2004). *Research methodology*. New Age International Publishers.

Lemike, S., Sinore, T., Wang, F., Zhao, Y., Girma, F., Getnet, G. T. & Kabato, W. S. (2026). Managing land degradation under changing climate in Ethiopia: A review of soil and water conservation practices, gaps, and pathways toward sustainable landscape. *Environmental Sciences Europe*, 38, Article 01474.

Mekonen, K. & Tesfahunegn, G. (2011). Impact assessment of soil and water conservation measures at Medego watershed in Tigray, Northern Ethiopia. *Maejo International Journal of Science and Technology*, 5(3), 312–330

Mohr, P. A. (1971). *The Geology of Ethiopia.* Haile Selassie I University Press.

Muche, K. & Molla, E. (2024). Assessing the impacts of soil water conservation activities and slope position on the soil properties of the Gelda watershed, Northwest Ethiopia. *Applied and Environmental Soil Science,* 2024, 6858460.

Mulugeta, D. & Stahr, K. (2010). Assessment of integrated soil and water conservation measures on key soil properties in South Gonder, north-western highlands of Ethiopia. *Soil Science and Environmental Management*, 1(7), 164-176.

Park, H. (2013). An introduction to logistic regression: From basic concepts to interpretation with particular attention to nursing domain. *Journal of Korean Academy of Nursing*, 43(2), 154–164.

Pimentel, D. (2006). Soil erosion: A food and environmental threat. *Environment,* *Development and Sustainability, 8*(1), 119–137.

Pla Sentís, I. (2002). Assessment of Environmental Impacts Derived of Soil and Water Conservation Practices. In: *Proceedings of the 12th ISCO Conference 282–290*. Tsinghua University Press.

Reddy, G. P. O., Kumar, N., & Singh, S. K. (2018). Remote sensing and GIS in mapping and monitoring of land degradation. In: *Geotechnologies and the Environment*, (pp. 401–424), Springer.

Slegers, M. F. W. (2008). If only it would rain: Farmers' perceptions of rainfall and drought in semi-arid central Tanzania. *Journal of Arid Environments*, 72, 2106–2123.

Tamiru, C. G. & Gemechu, S. O. (2016). Towards integrated soil erosion management in Elfeta District, West Shoa Zone, Oromia Regional State, Ethiopia. *Journal of Environment and Earth Science*, 6(9), 166–173.

Tegenge, M. & Biniam, S. (2017). *Estimating soil erosion risk and evaluating erosion control measures for soil conservation planning at Koga watershed in the highlands of Ethiopia*.

United Nations Convention to Combat Desertification, (2024). *Global land outlook thematic report on rangelands and pastoralists*. UNCCD.

Van Reeuwijk, L. P. (1992). *Procedures for soil analysis* (3rd ed.). International Soil Reference and Information Centre.

Waling, I., Van Vark, W., Houba, V. J. G. & Van der Lee, J. J. (1989). *Soil and plant analysis: A series of syllabi, Part 7: Plant analysis procedures.* Wageningen Agricultural University.

Walkley, A. & Black, I. A. (1934). An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science,* 37(1), 29-38.

Wassie, B. (2000). *Project planning, implementation and evaluation*. United Nations Centre for Regional Development, Africa Office.

Yericho, B. & Belay, S. (2015). Assessment of the effectiveness of watershed management intervention in Chena District, Kaffa Zone, Southwestern Ethiopia. *Journal of Water Resource and Protection,* 7(15), 1257–1269.

Yericho B. (2019). Technical viability of physical soil and water conservation structures implemented in Lake Hawassa watershed, southern Ethiopia. *Journal of Soil Science and Environmental Management,* 10(4), 68–74.