

Research Article

Effect of Soil Management Practices on Soil Physico-Chemical Properties: A Case of Wera Sub-Watershed, Southern Ethiopia

Tamrat Sinore ¹, Mulatu Chernet,¹ Kibemo Detamo,² and Mekiso Yohannes³

¹Department of Natural Resource Management, Wachemo University, Hossana, Ethiopia

²Department of Geography and Environmental Studies, Wachemo University, Hossana, Ethiopia

³Department of Plant Science, Wachemo University, Hossana, Ethiopia

Correspondence should be addressed to Tamrat Sinore; tame.eiar@gmail.com

Received 7 June 2022; Revised 11 August 2022; Accepted 17 August 2022; Published 16 September 2022

Academic Editor: Claudio Cocozza

Copyright © 2022 Tamrat Sinore et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Soil degradation is a global challenge for agricultural productivity. To tackle this, the Ethiopian government and different NGOs launched soil management technologies in different parts of Ethiopia, including the Wera sub-watershed in Anlemo district, southern Ethiopia. This study was carried out to investigate the effect of soil management practices on soil properties at various landscape positions in the Wera sub-watershed. To achieve the intended objective, the 27 composite soil samples were collected from soil bund with desho grass, fanya-juu with desho grass and no management practices (control) with three replications at three landscape positions from 0 to 30 cm depth whereas, 27 undisturbed soil samples were collected for bulk density analysis. The collected soil samples were analyzed for soil texture, soil reaction, cation exchange capacity, organic carbon, total nitrogen, and available phosphorus. The result showed that soil bund with desho grass and fanya-juu with desho grass were significantly influenced selected soil physico-chemical properties when compared with no management measures. In addition, landscape position has significantly ($p \leq 0.05$) influenced the selected physico-chemical properties of soil. Hereafter, soil bund with desho grass and fanya-juu with desho grass practices were found to be effective in changing landscape positions and advancing soil productiveness. Therefore, implementing soil bund with desho grass and fanya-juu with desho grass by considering landscape position is vital for increasing soil productivity via minimizing soil loss.

1. Introduction

Soil degradation, in terms of its quality and productivity due to improper use, is a major global issue and will remain high on the international agenda in the 21st century due to its effects on agronomic productivity, the environment, and food security [1]. Various sources suggest that 5-6 million hectares of arable land worldwide are being lost annually to severe degradation [2]. Soil conservation is a requirement for reducing soil fertility depletion and achieving sustainable land management in developing countries, where agriculture is the primary source of labor and food for an expanding population. Although conservation and productivity should always go hand in hand, this is not always the case. Soil conservation should increase agricultural output rather than decrease it. Agriculture is the backbone of the Ethiopian

economy, accounting for roughly 41% of GDP, 84% of total exports, and 80% of employment [3–5]. However, soil erosion [6, 7] and declining soil fertility [8, 9] severely limit agricultural productivity. According to [10], annual soil loss is estimated to be 1.5 billion metric tons, with 50% of this occurring on croplands, a problem that is especially severe in Ethiopia's highlands [11, 12].

The main challenges of soil management practices in Ethiopia include an emphasis on physical measures (soil bunds, Fanya-juu, and so on), implementing uniform technologies for all agro-ecologies, a failure to integrate physical measures with biological practices, a top-down extension approach, and a lack of attention to indigenous knowledge [13, 14]. Because of the issues presented, soil management initiatives in Ethiopia, particularly the Wera sub-watershed, have been less successful. Additionally, there

was less emphasis on combining physical measures with biological practices (such as the soil bund with desho grass and the fanya-juu with desho grass), there was poor public participation at various stages, and there was less of a push to preserve indigenous soil conservation practices. As a result, [15] noted that public and private supporters deploy soil bunds with desho grass (*P. pedicellatum*) across the slope in densely populated highland for sustainable soil and water conservation programs, including the Wera sub-watershed.

High rates of soil erosion are caused by erosive tropical rains, steep slopes, extensive deforestation for fuelwood collection, the expansion of cultivation into steep land areas, overgrazing, long periods of maladapted agricultural practices, and high population pressure [16–18]. Many studies in Ethiopia confirmed the positive impacts of soil and water conservation practices on soil physico-chemical properties and crop yields [19]. Soil conservation practices tested in Simada district, northwest Ethiopia, significantly improved soil physico-chemical properties [19], with significant differences in clay content between soil bund with desho grass, fanya-juu with desho grass, and control fields. A significantly higher amount of clay content was also found in fields with soil management practices compared to fields without conservation measures. Similarly, significantly lower mean bulk density was found in fields treated with soil management practices than in the untreated fields in Adaa Berga district, western Ethiopia [20]. Other studies conducted in Ethiopia also verified the positive impacts of soil and water conservation practices on soil physico-chemical properties and crop yields [8, 9, 12, 21]. Moreover, [12] evaluated the 20-year-old soil and water conservation practices on slope gradient, and found a 2.7% slope reduction on average because of the trapped sediment. The soil and water conservation practices improve the soil physico-chemical properties [19, 20] and reduce land degradation neutrality challenges [22, 23] and thereby will help to attain the 2030 United Nations Sustainable Development Goals, such as ending poverty, ending hunger, good health and well-being, sustainable economic growth, sustainable production, climate change mitigation, and halting and reversing land degradation.

In Ethiopia, although many studies confirmed the positive impacts of physical soil and water conservation practices on soil physico-chemical properties and crop yields, farmers frequently destroy soil and water conservation measures constructed on their fields, claiming that the practices did not show a positive impact/effect other than occupying their farmlands and the limitation of integrated (physical and biological) soil management practices on soil properties. Such claims need analysis and measured data to design alternative soil management strategies. Moreover, understanding how soil management practices reduce soil erosion and the loss of soil nutrients is important to show and prove to farmers the effectiveness of such practices.

Therefore, this study examined the effects of implementing soil bund with desho grass, fanya-juu with desho grass, and no soil management at different landscape positions on soil properties in Wera sub-Watershed in Anlemo district, in southern Ethiopia.

2. Materials and Methods

2.1. Study Area Description. This study was conducted in Wera sub-watershed which is located in Anlemo District of Hadiya Zone in southern Ethiopia. The District is 210 km far from Addis Ababa and 18 km from Hosanna which is capital town of Hadiya Zone. Geographically, it is located at 7°54'7.7"N latitude and 37°89'38.06"E longitude (Figure 1). It is also located at North Silte zone, at South Lemo Woreda, at East Shashogo Woreda and at West Misha Woreda of Hadiya Zone [24].

The common vegetation in the study area includes: *Croton macrystachys*, *Cordia africana*, and *Podo carpus*. The district received 1001 to 1200 mm mean annual rainfall and average temperature of 15°C to 20°C. The rainfall distribution is characterized as bimodal and erratic, the small rainy season from March to April, and the main rainy season from June to October. On the other hand, the Community of district depends on mixed agriculture (crop and livestock production). The annual crops grown are wheat, teff, potatoes, barley, maize, pea, cabbage, carrots, and onions whereas, perennial grown crops are enset, chat, sugarcane, and avocados [24].

2.2. Method of Data Collection. In this research, both primary and secondary data sources were used. The primary data were obtained from soil analysis and field observation, whereas the secondary data were obtained from published sources.

2.2.1. Study Site Selection. The Wera-sub watershed in Anlemo district was purposively selected due to the presence of intensive watershed management measures with similar ages, such as soil bund with desho grass, fanya-juu with desho grass, and adjacent non-conservation measures, which are implemented by Sustainable Land Management Project before 10 years ago. According to the information obtained from District Agricultural office, among the watershed management measures implemented by the project, soil bund with desho grass and fanya-juu with desho grass were common in the cultivated fields of the sub-watershed. Hence, the soils treated with soil bund with desho grass, fanya-juu with desho grass, and adjacent non-conservation measures as a control were considered for this study. The details of the conservation measures are described in Table 1.

2.2.2. Sampling Procedure. The purpose of this study was to analyze the effects of soil management practices (soil bund with desho grass, fanya-juu with desho grass, and no conservation measures) on selected soil physico-chemical properties at different landscape positions in the study area. The composite soil samples were randomly taken by using augur from soils treated with soil bund with desho grass, fanya-juu with desho grass, and adjacent non-conservation measures at three landscape positions (upper, middle, and lower) with three replication at the depth of 0–20 cm. In total, 27 composite soil samples (3 * 3 * 3) (i.e., three soil

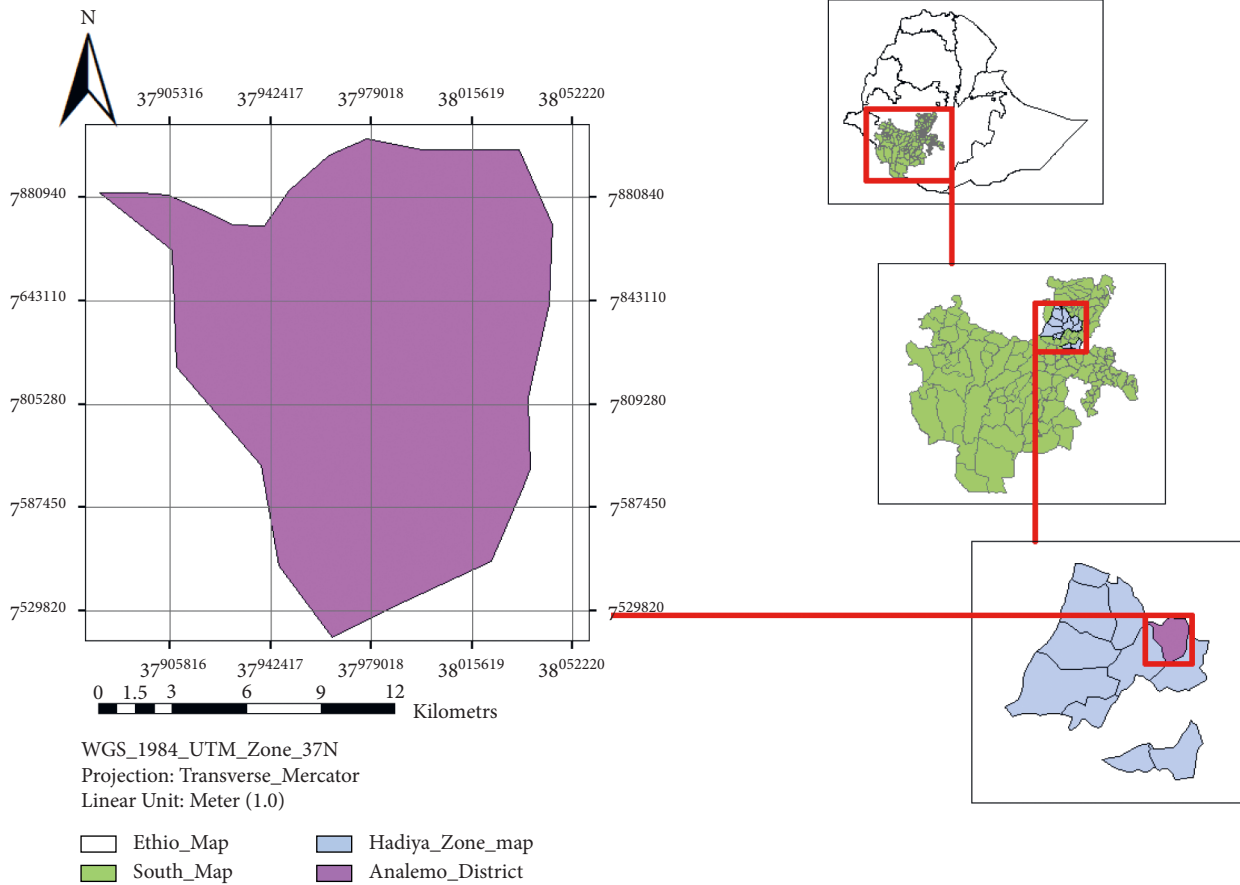


FIGURE 1: Location map of study area.

TABLE 1: Description of soil management practices in the study area.

Soil management measures	Descriptions
(i) Soil bund with desho grass	This category of cultivated field consisted 10 year soil bund with desho grass
(ii) Fanya-juu with desho grass	This category of cultivated field consisted 10 year fanya-juu with desho grass fanya-juu with desho grass
(iii) No conservation measure	This category of cultivated field is no conservation measure at all

management measures * three landscape positions * three replication) were collected for selected soil physical (soil texture and bulk density) and chemical (pH, organic carbon, total nitrogen, available phosphorus, and Cation exchange capacity) properties analysis. Whereas, undisturbed soil sample was collected using core-sampling method [25] to determine soil bulk density. The history of soil management practices, particularly fertilizer application, was recorded in all cases, and all key informants interviewed responded that they use the same type and amount of fertilizer per hectare on their farm land with soil bund with desho grass, fanya-juu with desho grass, and no conservation measure. The farm lands from where the soil samples taken were under wheat cultivation.

2.2.3. Soil Laboratory Analysis. The collected soil samples were air-dried, mixed well, and passed through a 2-mm sieve to analyze the texture and bulk density. Determinations of particle size distribution were carried out by the hydrometer method [26]. Hydrogen peroxide (H₂O₂) was used to

destroy the soil organic matter and sodium hexa metaphosphate (NaPO₃)₆ as well as sodium carbonate (Na₂CO₃) was used as soil dispersing agent and also one or two drops of amyl alcohol was used for foam reduction.

The bulk density of an undisturbed soil sample was determined using the core method [25] by weighing the wet core and determining the mass of solids and water content of the core by drying it to constant weight in an oven at 105°C for 24 hours and calculated as given in equation (1).

$$BD = \frac{Mcs - Mc}{Vc}, \tag{1}$$

where BD = Bulk density in gcm⁻³, Mcs = the mass of each core with its dry soil in g, Mc = the mass of each empty core in g, and Vc = Volume of core in cm³

Soil pH was measured using the glass electrode method with in a supernatant suspension of a 1 : 2.5 soil: liquid on a mass to volume basis. Earlier than use, the pH meter was calibrated with buffer solutions of pH 7 as its necessity. After 30 minute of stirring, the pH was measured in the

TABLE 2: Effect of soil management practices at different landscape positions on soil physical properties.

Soil properties	Landscape positions	Soil management practices			
		SBD	FD	NSC	Overall
Sand (%)	Upper (>30%)	36.00 ± 3.4 ^c	35.33 ± 1.15 ^c	46.00 ± 0.00 ^a	39.11 ± 5.49 ^A
	Middle (15–30%)	21.33 ± 2.3 ^a	21.33 ± 1.15 ^a	34.00 ± 2.00 ^b	25.56 ± 6.54 ^B
	Lower (<15%)	18.00 ± 0.0 ^b	17.33 ± 1.15 ^b	20.67 ± 2.31 ^c	18.67 ± 2.00 ^C
	Overall	25.11 ± 8.5 ^b	24.66 ± 8.25 ^b	33.56 ± 11.08 ^a	
	LSD 5%		1.8282		
Silt (%)	Upper (>30%)	28.00 ± 1.1 ^d	28.67 ± 2.31 ^d	24.00 ± 1.15 ^c	26.89 ± 2.67 ^C
	Middle (15–30%)	36.00 ± 2.00 ^b	35.33 ± 1.15 ^b	30.67 ± 3.05 ^d	34.00 ± 3.16 ^B
	Lower (<15%)	36.67 ± 0.0 ^b	37.33 ± 1.15 ^b	40.67 ± 1.15 ^a	38.22 ± 2.11 ^A
	Overall	33.56 ± 4.3 ^a	33.78 ± 4.17 ^a	31.78 ± 7.51 ^b	
	LSD 5%		1.7469		
Clay (%)	Upper (>30%)	36.00 ± 3.46 ^a	36.00 ± 3.46 ^a	30.00 ± 2.00 ^b	34.00 ± 4.00 ^B
	Middle (15–30%)	42.67 ± 3.05 ^b	43.33 ± 1.15 ^b	35.33 ± 4.62 ^a	40.44 ± 4.70 ^A
	Lower (<15%)	45.33 ± 1.15 ^b	45.33 ± 2.31 ^b	38.67 ± 1.15 ^a	43.11 ± 3.62 ^A
	Overall	41.33 ± 4.8 ^a	41.56 ± 4.94 ^a	34.66 ± 4.58 ^b	
	LSD 5%		2.7223		
BD (g/m ³)	Upper (>30%)	1.01 ± 0.03 ^b	0.98 ± 0.07 ^b	1.13 ± 0.11 ^a	0.99 ± 0.09 ^A
	Middle (15–30%)	0.97 ± 0.07 ^b	0.94 ± 0.09 ^b	1.08 ± 0.09 ^a	0.86 ± 0.11 ^A
	Lower (<15%)	0.83 ± 0.02 ^c	0.78 ± 0.11 ^c	0.98 ± 0.02 ^b	1.04 ± 0.07 ^B
	Overall	0.94 ± 0.09 ^b	0.90 ± 0.12 ^b	1.06 ± 0.06 ^a	
	LSD 5%		0.0621		

At $p < 0.05$, mean values followed by different small letters (a, b, c) along the same rows and capital letters (A, B, C) along the same column differ significantly. LSD stands for least significant difference, BD stands for bulk density, SBD stands for soil bund with desho grass, FD stands for fanya-juu with desho grass, and NSC stands for non-soil conservation practices as a control.

suspension by using a standard pH meter and the liquid was water.

Soil organic carbon was determined by using Walkley and Black wet digestion method. One Gram of soil was reacted with a mixture of 10 mL of 1 N $K_2Cr_2O_7$ solution and 20 mL of 98% H_2SO_4 . After adding 200 mL distilled water, 10 mL of 85% H_3PO_4 , and 1 mL of indicator solution (0.16 percent barium diphenylamine sulfate), the excess dichromate solution was titrated against 1 M ferrous sulfate, and finally values of soil organic carbon were multiplied by a factor of 1.724 to obtain soil organic matter using the standard practice that organic matter is composed of 58 percent carbon [27]. The available phosphorus content of the soil was analyzed using 0.5 M sodium bicarbonate extraction solution (pH < 7) of Bray II method [28]. Total nitrogen was identified by using Kjeldahl digestion procedure [29]. Cation exchange capacity (CEC) was determined after extracting the soil samples by ammonium acetate method (1N NH_4OAc) at pH 7.0 [26].

2.3. Data Analysis. The Analysis of Variance (ANOVA) was performed to test the differences in the soil properties due to different soil management measures. The difference was determined following the General Linear Model procedure at $p \leq 0.05$ level using SAS 9.2. Mean separation was done using least significant difference (LSD) at $p \leq 0.05$. Furthermore, correlation analysis was employed to ascertain the relationship between the selected soil properties and soil management measures.

3. Result and Discussion

3.1. Effects of Soil Management Practices on Soil Physical Properties

3.1.1. Soil Texture. The sand, silt, and clay fractions were significantly affected ($p \leq 0.05$) by soil management practices and landscape positions (Table 2) in the study catchment. The overall mean of sand fraction was higher in the upper landscape position and lower in the lower landscape positions. In general, sand content increases as landscape positions increase, and silt and clay content decreases as landscape positions increase.

This might be the selective removal and transport of soil clay and silt by water erosion to the lower landscape positions, leaving the coarser materials on-site in the upper landscape positions. Similarly, [8] has reported an increase in sand and decrease in silt and clay content with an increase in slope gradient. In addition to this, [30] has indicated sands are easily detachable but difficult to transport. In contrast, silt and clay are easily transportable although they are difficult to detach from runoff.

On the other hand, there was a significant ($p \leq 0.05$) difference found in sand, silt, and clay proportion between conservation practices and without conservation practices. The overall mean of clay and silt content on land with conservation measures was significantly higher than on land without conservation measures, whereas the sand fraction was significantly lower on land with conservation measures than on land without conservation measures (Table 2). This could be due to the accumulation of fine textured clay and

TABLE 3: Pearson correlation matrix for the selected soil properties in the study area.

	BD	Sand	Silt	Clay	Av.P	TN	CEC	pH	OC
BD	1.00*								
Sand	0.05 ⁿ	1.00*							
Silt	0.37*	0.02 ⁿ	1.00*						
Clay	-0.24*	-0.60*	-0.66*	1.00*					
Av.P	-0.47*	0.00	-0.21*	0.17*	1.00*				
TN	-0.30*	-0.17 ⁿ	-0.23*	0.32*	0.47*	1.00*			
CEC	-0.16 ⁿ	-0.71*	-0.06 ⁿ	0.60*	0.39*	0.34*	1.00*		
pH	-0.04 ⁿ	0.17 ⁿ	-0.30*	0.35*	0.04 ⁿ	0.41*	0.05 ⁿ	1.00*	
OC	-0.31*	-0.16 ⁿ	-0.30*	0.37*	0.44*	0.99*	0.36*	-0.40*	1.00*

*-stands for significant, *n*-stands for not significant. BD stands for bulk density, Av.P stands for available phosphorus, TN stands for total nitrogen, CEC stands for cation exchange capacity, pH stands for potential for hydrogen, and OC stands for organic carbon.

silt fractions behind the implemented conservation measures. Furthermore, fields with soil and water conservation practices had higher clay and silt proportions than fields with no conservation practices [19, 31, 32].

3.1.2. Soil Bulk Density. There was a statistically significant ($p \leq 0.05$) difference in soil conservation practices treated versus untreated fields and landscape positions (Table 2). The soil bulk density was lower in soil bund with desho grass and fanya-juu with desho grass than besides no soil management practices. The higher bulk density in the cultivated field with no soil management practices could be due to erosion and runoff removing organic carbon from the topsoil layer. Similarly, lower soil bulk density [20, 33] was observed in treated watersheds than untreated watersheds.

In addition, soil bulk density showed statistically significant ($p \leq 0.05$) variation at different landscape positions (Table 2). It was found to be lower in the lower (<15%) landscape position than in the upper (>30%) landscape position. As landscape position increases, soil bulk density increases, which might be associated with low soil organic carbon content. Similarly, [20] reported lower soil bulk density was observed in cultivated fields of lower slope positions than in the upper slope positions. In addition to this, there was a direct relationship [9, 34] of soil bulk density and slope gradient. This study discovered a significant and negative correlation between bulk density and clay fraction ($r = -0.24^*$); a non-significant and positive correlation between bulk density and sand fraction ($r = 0.05$); and a significant and negative correlation between bulk density and organic carbon ($r = -0.31^*$) (Table 3). The reason might be related with variations in soil organic matter content, which has an inverse relationship with soil bulk density. In general, soil texture and bulk density did not differ significantly ($p > 0.05$) between two soil management practices (soil bund with desho grass and fanya-juu with desho grass), which could be attributed to the practices' similar ages.

3.2. Effects of Soil Management Practices on Soil Chemical Properties. In this part, the effects of soil management practices (soil bund with desho grass and fanya-juu with desho grass) on soil chemical properties (Soil pH, CEC, OC, Av.P, and TN) were presented as follows:

3.2.1. Soil pH. The soil pH showed a significant different ($p \leq 0.05$) between soil with management practices and soil with no management practices in the study area (Table 4). The overall mean of soil bund with desho grass was (6.51 ± 0.32), fanya-juu with desho grass was (6.48 ± 0.26), and overall mean of no management practices was (5.90 ± 0.48) (Table 4). This might be organic matter removal by sheet erosion from soil without conservation fields. This finding was supported by [8] in the Weday watershed, eastern Ethiopia. Similarly [35], low pH value was observed in untreated fields due to low base saturation percentages and low sediment organic carbon content when compared with soil management practices.

Soil pH variations were significant ($p < 0.05$) in different landscape positions. The overall mean value of soil pH was found to be low in the upper (>30%) landscape position and high in the lower (<15%) landscape position. As the landscape position increases, soil pH decreases. The reason might be the influence of landscape position by its effect of facilitating soil erosion and the leaching of soluble base cations which in turn increased the concentration of H^+ ion in the soil solution and reduced soil pH. The difference in soil pH across the landscape position might be associated with the distribution of soil organic carbon and cation exchange capacity as pH is positively and significantly correlated with soil organic carbon, cation exchange capacity, and clay fraction ($r = 0.40^*$, $r = 0.05$, and $r = 0.35^*$, respectively, Table 3).

3.2.2. Cation Exchange Capacity (CEC). This finding showed there was significant difference ($p \leq 0.05$) between cultivated fields with soil management practices and without soil management practices in the study area (Table 4). In the study, area cation exchange capacity was significantly influenced by the soil management practices (soil bund with desho grass and fanya-juu with desho grass) which could be due to the trapping and accumulation of soil organic matter via management practices. This was confirmed by the significant and positive relationship between soil organic carbon ($r = 0.36^*$) and clay content ($r = 0.60^*$) and cation exchange capacity (Table 3). This finding was in line with [8, 19] reported higher mean values of cation exchange capacity was found in the treated than in the untreated fields in central and eastern Ethiopia.

TABLE 4: Effect of soil management practices at different landscape positions on soil chemical properties.

Soil properties	Landscape positions	Soil management practices			
		SBD	FD	NSC	Overall
pH	Upper (>30%)	6.36 ± 0.06 ^b	6.35 ± 0.11 ^b	5.30 ± 0.10 ^c	6.01 ± 0.54 ^C
	Middle (15–30%)	6.27 ± 0.75 ^b	6.41 ± 0.32 ^b	6.06 ± 0.09 ^a	6.25 ± 0.23 ^B
	Lower (<15%)	6.81 ± 0.12 ^a	6.77 ± 0.36 ^a	6.35 ± 0.07 ^b	6.65 ± 0.29 ^A
	Overall	6.48 ± 0.26 ^a	6.51 ± 0.32 ^a	5.90 ± 0.48 ^b	
	LSD 5%		0.1769		
CEC (cmol.kg ⁻¹)	Upper (>30%)	30.40 ± 0.87 ^b	21.10 ± 1.27 ^c	18.88 ± 2.00 ^c	23.46 ± 5.44 ^C
	Middle (15–30%)	38.53 ± 1.39 ^a	28.40 ± 4.95 ^b	21.47 ± 3.92 ^d	29.47 ± 8.10 ^B
	Lower (<15%)	40.60 ± 3.07 ^a	40.69 ± 8.94 ^a	28.24 ± 4.69 ^b	36.51 ± 8.14 ^A
	Overall	36.51 ± 4.98 ^a	30.06 ± 10.0 ^b	22.86 ± 5.28 ^c	
	LSD 5%		4.1688		
OC (%)	Upper (>30%)	1.39 ± 0.06 ^c	1.25 ± 0.15 ^c	0.92 ± 0.16 ^b	1.18 ± 0.24 ^C
	Middle (15–30%)	2.42 ± 0.31 ^b	1.82 ± 0.21 ^d	1.58 ± 0.19 ^d	1.94 ± 0.43 ^B
	Lower (<15%)	2.79 ± 0.07 ^a	2.21 ± 0.31 ^b	1.81 ± 0.30 ^c	2.27 ± 0.48 ^A
	Overall	2.20 ± 0.65 ^a	1.76 ± 0.47 ^b	1.44 ± 0.45 ^c	
	LSD 5%		0.2157		
TN (%)	Upper (>30%)	0.29 ± 0.00 ^d	0.21 ± 0.02 ^c	0.14 ± 0.01 ^b	0.22 ± 0.01 ^C
	Middle (15–30%)	0.32 ± 0.0 ^b	0.30 ± 0.00 ^b	0.17 ± 0.01 ^a	0.26 ± 0.07 ^B
	Lower (<15%)	0.43 ± 0.03 ^a	0.42 ± 0.03 ^a	0.26 ± 0.06 ^c	0.37 ± 0.10 ^A
	Overall	0.35 ± 0.07 ^a	0.31 ± 0.09 ^b	0.19 ± 0.06 ^c	
	LSD 5%		0.0279		
Av.P (mg.kg ⁻¹)	Upper (>30%)	6.64 ± 0.13 ^c	6.62 ± 0.45 ^c	5.54 ± 1.45 ^c	6.27 ± 0.94 ^C
	Middle (15–30%)	14.66 ± 3.64 ^d	10.96 ± 1.09 ^a	7.17 ± 0.30 ^b	10.93 ± 3.76 ^B
	Lower (<15%)	17.56 ± 1.40 ^b	19.60 ± 0.74 ^b	11.12 ± 2.90 ^a	16.09 ± 3.94 ^A
	Overall	12.95 ± 5.27 ^a	12.4 ± 5.76 ^a	7.94 ± 2.63 ^b	
	LSD 5%		1.4833		

At $p \leq 0.05$, mean values followed by different small letters (a, b, c) along the same rows and capital letters (A, B, C) along the same column differ significantly.

Even though, the cation exchange capacity showed a significant ($p \leq 0.05$) difference at different landscape positions, it was discovered to be low in the upper (>30%) landscape positions and high in the lower (<15%) landscape positions. As the landscape positions increased, the CEC value decreased. This could be due to the removal of basic cations from the upper (>30%) landscape positions, and accumulation in the lower (<15%) landscape positions. This finding was in line with [8, 19] reported higher CEC values in the lower (<15%) landscape positions than those in the upper (>30%) landscape positions in central and eastern Ethiopia.

3.2.3. Soil Organic Carbon (OC). The organic carbon content was significantly ($p \leq 0.05$) affected by soil management practices when compared with adjacent no management practices (Table 4). It was significantly lower under no management practice (1.44 ± 0.45) compared to soil bund with desho grass (2.20 ± 0.65) and fanya-juu with desho grass (1.76 ± 0.47) (Table 4). The soil organic carbon also showed a significant variation ($p \leq 0.05$) between the different landscape positions (Table 4). The higher soil organic carbon was observed at lower landscape position than upper landscape positions. It showed an inverse relationship with landscape positions that means as landscape position increases, soil organic matter decreases. This might be associated with the removal of organic matter from upper landscape positions and its subsequent deposition in the lower landscape positions via eroding agents. This finding

was consistent with the findings of [36, 37] who found that fertile soil deposition at lower slopes favored high biomass, residue, and soil organic carbon in northern and northwest Ethiopia. The lands with management practices that provide mechanical barriers to the runoff water would have reduced the loss of fine soil fractions and organic carbon, that is, because clay particles have large exchange surface areas, they adsorb and stabilize OC in soils. That means soil management practices such as soil bund with desho grass and fanya-juu with desho grass might add organic matter to the soils through biomass besides controlling soil erosion.

3.2.4. Total Nitrogen (TN). The total nitrogen was significantly affected ($p \leq 0.05$) by different soil management practices and landscape conditions. It was significantly lower with no management (0.19 ± 0.06) compared to soil bund with desho grass (0.35 ± 0.07) and fanya-juu with desho grass (0.31 ± 0.09) (Table 4). This might be due to integrated use of desho grass with physical soil management practices which improves soil organic carbon and reduced soil loss via soil erosion.

The soil management practices reducing runoff and soil loss and enhancing profile water storage would contribute to soil organic matter and nitrogen input in the soil. For instance, non-conserved land had the smallest mean value of total nitrogen compared to the conserved land [21, 32]. The Pearson correlation coefficient also revealed that TN significantly and positively correlated with soil organic carbon ($r = 0.99^*$) (Table 3). This is because SOM is the main source

TABLE 5: Effect of soil management practices on inter-terrace slope of the study watershed.

Soil management practices	Mean inter-terrace slope (%)	Height of bunds(cm)
Soil bund with desho grass	7.16 ^b	80.0 ^a
Fanya-juu with desho grass	8.00 ^b	67.0 ^b
No conservation practices (control)	19.50 ^a	00.00 ^c
LSD	11.64	9.08
CV	49.67	9.28

At $p \leq 0.05$, mean values followed by different letters (a, b, c) are significantly different and CV, coefficient of variation.

of TN. Because of increased biomass production, litter quantity, and organic matter decomposition, TN also correlated positively with SOC. In general, TN was low in the untreated fields and medium in the treated fields which indicates that nitrogen is a limiting plant nutrient in the study area. This might be due to the limited use of nitrogen-containing inputs.

3.2.5. Available Phosphorus (Av.P). Soil management practices and landscape positions had a significant ($p < 0.05$) effect on soil available phosphorus (Table 4). The highest (12.95 ± 5.27 mg/Kg) and the lowest (7.94 ± 2.63 mg/Kg) Av.P contents were observed under the soil bund with desho grass and no soil management practices, respectively (Table 4). The reason might be due to the fact that the integration of physical and biological soil management (soil bund and fanya-juu with desho grass) practices add mineral and organic fractions in soil, besides intensity of soil weathering and P fixation as a result of decreased soil erosion. Whereas, low available phosphorus in no soil management practice was due to continuous cultivation and high erosion. This finding was supported by [8, 21] reported fields without soil and water conservation has extractive crops biomass harvest and soil erosion in eastern and southern Ethiopia. Besides, Av.P of the soil was positively and significantly correlated with total nitrogen ($r = 0.47^*$) and organic carbon ($r = 0.44^*$) (Table 3). Also, [21] reported significantly higher contents of available phosphorus in conserved compared to non-conserved fields which means that the main effect of slope range also revealed that available P was significantly higher in the lower slope than in the upper slope because of its removal from the upper slope and deposition in the lower slope.

As presented in Table 4, available phosphorus was significantly ($p \leq 0.05$) affected by landscape positions in the study area. The highest available phosphorus (16.09 ± 3.94) was found in the lower (<15%) landscape position, while the lowest (6.27 ± 0.94) mean value was found in the upper (>30%) landscape position. The reason for this could be due to the washing away of topsoil and organic matter from higher landscape positions and their subsequent accumulation at lower landscape positions, as [8] found in the Weday watershed in eastern Ethiopia.

3.3. Effect of Soil Management Practices on Landscape Position Change. The mean inter-terrace slope position showed a significantly ($p \leq 0.05$) difference between the plots with soil management practices and no conservation practices. The mean inter-terrace slope position in the soil management

practices was found to be low compared with the no conservation practices (Table 5). However, the mean inter-terrace slope positions between soil bund with desho grass and fanya-juu with desho grass did not show a significant ($p > 0.05$) difference. The deposition of soil materials and debris on the upper position of soil bund with desho grass and fanya-juu with desho grass (usually called accumulation zone) causes the height of the bunds to improve year after year, thereby reducing the inter-terrace slope position between two successive structures.

4. Conclusion

In the study area, soil bund with desho grass and fanya-juu with desho grass was implemented at different landscape positions by communities with the aid of a Sustainable Land Management project to minimize soil loss and enhance soil productivity. Therefore, this study was carried out to see the performance of soil bund and fanya-juu with desho grass on soil properties at different landscape positions. Accordingly, soil properties were positively influenced by soil bund with desho grass and fanya-juu with desho grass when compared with no soil management practices. Clay, sand, silt, bulk density, total nitrogen, available phosphorus, soil organic carbon, soil pH, and cation exchange capacity, for example, showed a significant difference in the different landscape positions between soil with management practices (soil bund and fanya-juu with desho grass) and soil with no management practices. The fields with a lower landscape position have high mean values of clay, silt, total nitrogen, available phosphorus, soil organic carbon, soil pH, and cation exchange capacity) except for bulk density and sand content. In conclusion, implementing soil bund and fanya-juu with desho grass in the appropriate landscape position improved selected soil physico-chemical properties in the study areas.

Data Availability

The data that were used to create this manuscript are available upon request from the corresponding author.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Acknowledgments

The authors would like to thank Wachemo University for financial support and farmers of Wera sub-watershed for their participation during data collection.

References

- [1] T. Gashaw, "Working group on land degradation and desertification of the international union of soil sciences," in *Proceedings of the Second International Conference on Land Degradation and Desertification*, Khon Kaen, Thailand, 1999.
- [2] A. Hamdy and A. Aly, "Land degradation, agriculture productivity and food security," in *Proceedings of the Fifth International Scientific Agricultural Symposium*, pp. 708–717, Agrosym, Jahorina Bosnia and Herzegovina, 2014.
- [3] A. Muluneh, B. Biazin, L. Stroosnijder, W. Bewket, and S. Keesstra, "Impact of predicted changes in rainfall and atmospheric carbon dioxide on maize and wheat yields in the Central Rift Valley of Ethiopia," *Regional Environmental Change*, vol. 15, no. 6, pp. 1105–1119, 2015.
- [4] P. Matouš, Y. Todo, and D. Mojo, "Roles of extension and ethno-religious networks in acceptance of resource-conserving agriculture among Ethiopian farmers," *International Journal of Agricultural Sustainability*, vol. 11, no. 4, pp. 301–316, 2013.
- [5] N. Haregeweyn, A. Tsunekawa, J. Nyssen et al., "Soil erosion and conservation in Ethiopia: a review," *Progress in Physical Geography: Earth and Environment*, vol. 39, no. 6, pp. 750–774, 2015.
- [6] M. Mekonnen, S. D. Keesstra, L. Stroosnijder, J. E. M. Baartman, and J. Maroulis, "Soil conservation through sediment trapping: a review," *Land Degradation & Development*, vol. 26, no. 6, pp. 544–556, 2015.
- [7] A. Teshome, J. de Graaff, and M. Kassie, "Household-level determinants of soil and water conservation adoption phases: evidence from North-Western Ethiopian highlands," *Environmental Management*, vol. 57, no. 3, pp. 620–636, 2016.
- [8] D. Teresa, "The effectiveness of stone bund to maintain soil physical and chemical properties: the case of Weday watershed, East Hararge zone, Oromia, Ethiopia," *Civil and Environmental Research*, vol. 9, no. 12, pp. 9–18, 2017.
- [9] W. Hailu, A. Moges, and F. Yimer, "The effects of "fanya-juu" soil conservation structure on selected soil physical & chemical properties: the case of Goromti watershed, western Ethiopia," *Resources and Environment*, vol. 2, no. 4, pp. 132–140, 2012.
- [10] E. Assefa and B. Hans-Rudolf, "Farmers' perception of land degradation and traditional knowledge in Southern Ethiopia-resilience and stability," *Land Degradation & Development*, vol. 27, no. 6, pp. 1552–1561, 2016.
- [11] K. Welde, "Identification and prioritization of sub-watersheds for land and water management in Tekeze dam watershed, Northern Ethiopia," *International Soil and Water Conservation Research*, vol. 4, no. 1, pp. 30–38, 2016.
- [12] M. Mekonnen, S. D. Keesstra, J. E. M. Baartman, L. Stroosnijder, and J. Maroulis, "Reducing sediment connectivity through man-made and natural sediment sinks in the Minizr catchment, Northwest Ethiopia," *Land Degradation & Development*, vol. 28, no. 2, pp. 708–717, 2017.
- [13] H. Mitiku, K. G. Herweg, and B. Stillhardt, *Sustainable Land Management: A New Approach to Soil and Water Conservation in Ethiopia*, Centre for Development and Environment, Bern, Switzerland, 2006.
- [14] S. Umer, A. Aticho, and E. Kiss, "Effects of integrated use of grass strip and soil bund on soil properties, Southern Ethiopia," *Journal of Degraded and Mining Lands Management*, vol. 06, no. 02, pp. 1569–1578, 2019.
- [15] G. Smith, "Ethiopia: local solutions to a global problem," 2010, https://www.google.com/search?q=Ethiopia%3A+Local+Solutions+to+a+Global+Problem&rlz=1C1GCEB_enIN1005IN1005&oq=Ethiopia%3A+Local+Solutions+to+a+Global+Problem&aqs=chrome.69i57j69i58.202j0j9&sourceid=chrome&ie=UTF-8.
- [16] J. Nyssen, J. Poesen, J. Moeyersons, J. Deckers, M. Haile, and A. Lang, "Human impact on the environment in the Ethiopian and Eritrean highlands-a state of the art," *Earth-Science Reviews*, vol. 64, no. 3-4, pp. 273–320, 2004.
- [17] A. Amsalu, L. Stroosnijder, and J. d. Graaff, "Long-term dynamics in land resource use and the driving forces in the Beressa watershed, highlands of Ethiopia," *Journal of Environmental Management*, vol. 83, no. 4, pp. 448–459, 2007.
- [18] M. Mekonnen, S. D. Keesstra, C. J. Ritsema, L. Stroosnijder, and J. E. Baartman, "Sediment trapping with indigenous grass species showing differences in plant traits in northwest Ethiopia," *Catena*, vol. 147, pp. 755–763, 2016.
- [19] G. Mihrete, "Effect of soil conservation measures on some physico-chemical properties of soil and crop yield in Simada district, South Gondar zone, Ethiopia," Master 'thesis, Haramaya University, Dire Dawa, Ethiopia, 2014.
- [20] A. Challa, A. Abdelkadir, and T. Mengistu, "Effects of graded stone bunds on selected soil properties in the central highlands of Ethiopia," *International Journal of Natural Resource Ecology and Management*, vol. 1, no. 2, pp. 42–50, 2016.
- [21] M. Demelash and K. Stahr, "Assessment of integrated soil and water conservation measures on key soil properties in South Gonder, North-Western Highlands of Ethiopia," *Journal of Soil Science and Environmental Management*, vol. 1, no. 7, pp. 164–176, 2010.
- [22] S. D. Keesstra, J. Bouma, J. Wallinga et al., "The significance of soils and soil science towards realization of the United Nations Sustainable Development Goals," *Soils*, vol. 2, no. 2, pp. 111–128, 2016.
- [23] S. Keesstra, G. Mol, J. De Leeuw et al., "Soil-related sustainable development goals: four concepts to make land degradation neutrality and restoration work," *Land*, vol. 7, no. 4, p. 133, 2018.
- [24] S. Umer and T. Sinore, "Effects of area enclosure on soil properties and farmers' awareness towards the practice in Wera sub-watershed at analemo Woreda, southern Ethiopia," *International Journal of Agricultural and Environmental Sciences*, vol. 4, no. 1, pp. 1–7, 2019.
- [25] FAO, *Methods of Analysis for Soils of Arid and Semi-Arid Regions*, Food and Agriculture organization of the United Nations Rome, Rome, Italy, 2007.
- [26] V. J. G. Houba, J. J. Van der Lee, I. Novozamsky, and I. Walinga, *Soil and Plant Analysis, a Series of Syllabi, Part 5, Soil Analysis Procedures*, Wageningen Agricultural University, Wageningen, Netherlands, 1989.
- [27] D. A. Nelson and L. Sommers, "Total carbon, organic carbon, and organic matter," *Methods of soil analysis: Part 2 chemical and microbiological properties*, vol. 9, pp. 539–579, 1983.
- [28] L. P. Van Reeuwijk, *Procedures for Soil Analysis*, International Soil Reference and Information Center Wageningen, the Netherlands, Wageningen, Netherlands, 3rd edition, 1993.
- [29] J. M. Bremner, "Nitrogen-total. Methods of soil analysis: Part 3," *Chemical Methods*, vol. 5, pp. 1085–1121, 1996.
- [30] P. P. Sharma, S. C. Gupta, and G. R. Foster, "Raindrop-induced soil detachment and sediment transport from interrill areas," *Soil Science Society of America Journal*, vol. 59, no. 3, pp. 727–734, 1995.

- [31] J. Tugizimana, "Effects of soil and water conservation techniques on soil productivity and bean grain yield in Nyamashoke district, Rwanda," Kenyatta University, Nairobi, Kenya, 2015.
- [32] K. Wolka, A. Moges, and F. Yimer, "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," *Agricultural Sciences*, vol. 2, no. 3, pp. 357–363, 2011.
- [33] H. Worku, "Impact of physical soil and water conservation structure on selected soil physicochemical properties in Gondar Zuriya Woreda," *Resources and Environment*, vol. 7, no. 2, pp. 40–48, 2017.
- [34] A. Chimdi, H. Gebrekidan, K. Kibret, and A. Tadesse, "Status of selected physicochemical properties of soils under different land use systems of Western Oromia, Ethiopia," *Journal of Biodiversity and Environmental Sciences*, vol. 2, no. 3, pp. 57–71, 2012.
- [35] T. Amare, A. Terefe, Y. G Selassie, B. Yitaferu, B. Wolfgramm, and H. Hurni, "Soil properties and crop yields along the terraces and toposequence of Anjeni Watershed, Central Highlands of Ethiopia," *Journal of Agricultural Science*, vol. 5, no. 2, pp. 134–144, 2013.
- [36] A. Million, "Characterization of Indigenous Stone bunding (Kab) and its effect on crop yield and soil productivity at Mesobit-Gedba, North Showa Zone of Amhara Region," pp. 45–54, Alemaya University, Master of Science thesis, Dire Dawa, Ethiopia, 2003.
- [37] A. Hailelassie, J. Priess, E. Veldkamp, D. Teketay, and J. P. Lesschen, "Assessment of soil nutrient depletion and its spatial variability on smallholders' mixed farming systems in Ethiopia using partial versus full nutrient balances," *Agriculture, Ecosystems & Environment*, vol. 108, no. 1, pp. 1–16, 2005.